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MACHINE PLACEMENT OF FERTILIZERS FOR SNAP BEANS IN FLORIDA

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INTRODUCTION

Machine fertilizer-placement studies with snap beans were conducted near Winter Garden in Orange County, Fla., in 1931, 1932, and 1933, cooperatively by the Bureau of Agricultural Engineering and the Bureau of Plant Industry of the United States Department of Agriculture. The experiments were made on growers' farms [1] on Leon fine sand and St. John's fine sand, two of the principal soil types used for truck crops in this section of Florida. The work was undertaken at the suggestion of the director of the Florida Agricultural Experiment Station.

Approximately 40,000 acres of land are devoted annually to fall, winter, and spring production of beans in Florida, about 15,000 acres being grown in the fall. Orange County is near the center of the area devoted to fall growing of beans. The spring crops are grown principally in the southern and eastern sections of the State. Fall planting of beans extends from about July 15 to October 15.

Much of the area used for beans in the Winter Garden section is tile drained and subirrigated (fig. 1). Most of the land is used for growing field corn, but weeds and grass may be allowed to grow during the summer preceding fall planting of beans. In preparing the land this vegetation is plowed under a short time before planting (fig. 2), the plowing varying from 6 to 9 inches in depth. Thus, a mat of undecayed matter underlies the surface of the ground and often interferes with deep planting and cultural operations. After the land is plowed, it is disked, rolled, and dragged, to produce a firm, smooth seedbed. As a result of this cultural practice, shallow operations and the use of rotating soil-working tools are desirable.

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[1] The land for the experiments, and the labor for planting and cultivating, were furnished by P. H. Britt, L. L. Kenneday, H. C. Healan, A. R. Gano, and Kannon Bros., of Winter Garden, whose cooperation and assistance is acknowledged.

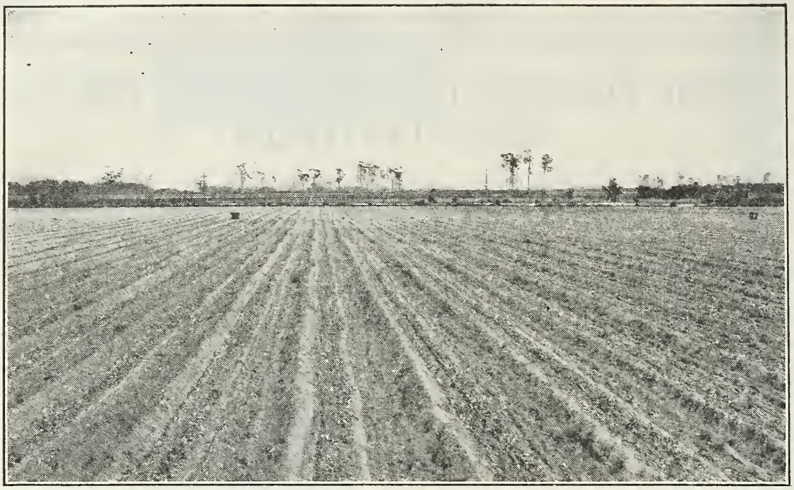

FIGURE 1.—Typical land on which green beans are grown near Winter Garden, Fla. Inlets to the combined subirrigation and drainage system are shown in the center and at the right of the field.

This practice is general with most farmers in the area devoted to fall production of beans. Planting practices and methods of fertilization, however, vary considerably. Planting is done with one-horse single-row planters having runner-type furrow openers and open press wheels, or with small push planters. Seeds are spaced about 3 inches apart in the row, which requires from 3 to 4 pecks per acre. Combination planters and fertilizer distributors are not used. The

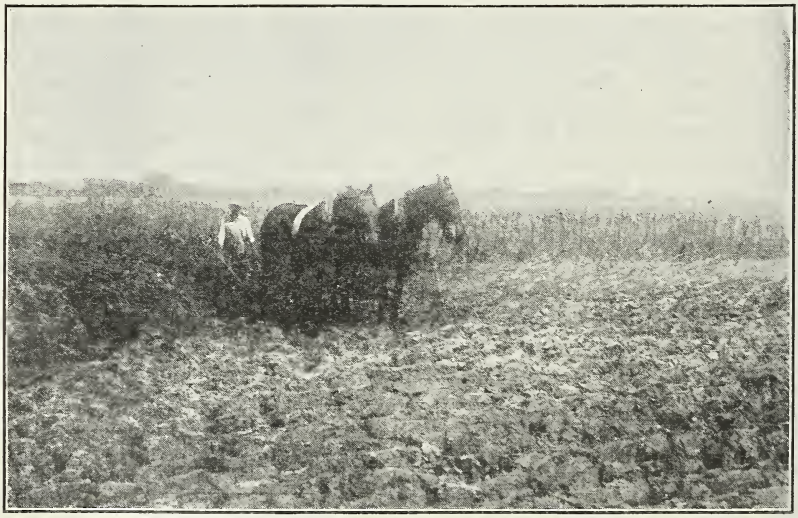

FIGURE 2.—The usual method of plowing land for green beans in central Florida. Heavy vegetative growth commonly plowed under is shown in the background.

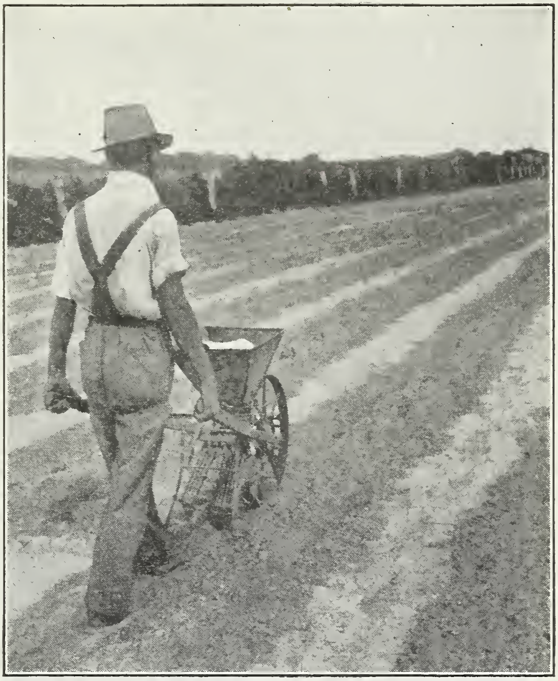

FIGURE 3.—Fertilizer distributor of the push type, locally known as a "Georgia buggy", used in Florida for applying fertilizer to the row before planting and for side applications to beans and other crops.

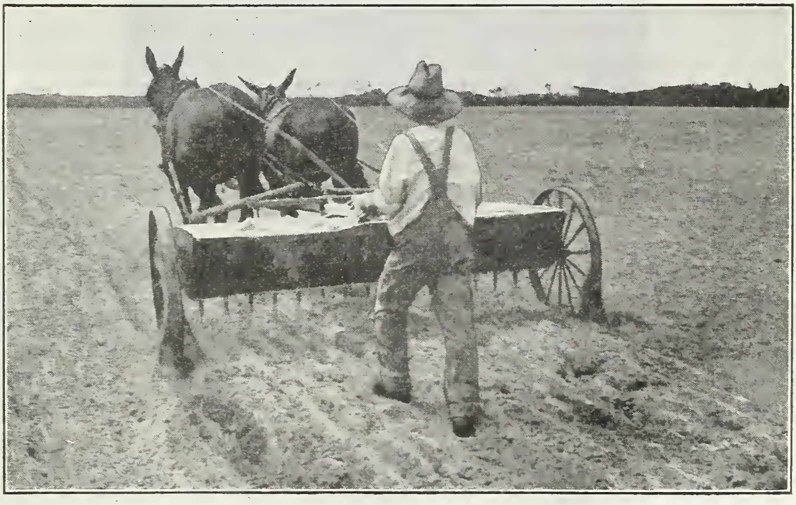

FIGURE 4.—Fertilizer broadcast distributor of a type commonly used for applying superphosphate, castor bean, and cottonseed meal to bean land in Florida before planting.

fertilizer is applied in one or more separate operations. One method commonly practiced is the application of fertilizer in the marked row previous to planting, the fertilizer being mixed with the soil with a cultivator or with a 4-inch shovel, or bedded on about 2 inches deep. When these methods are used the seed are planted in the fertilizer-soil mixture in the furrow or in the bed, respectively. A second procedure is broadcasting the fertilizer and incorporating it with the soil by disking and dragging. A third procedure is the application of the fertilizer as side dressings after the plants are up. In most cases where the first or second procedure is followed, additional applications of fertilizer are made as side dressings later in the season. Common types of row distributor, fertilizer broadcaster, and lettuce cultivator used for bean culture are illustrated in figures 3, 4, and 5, respectively.

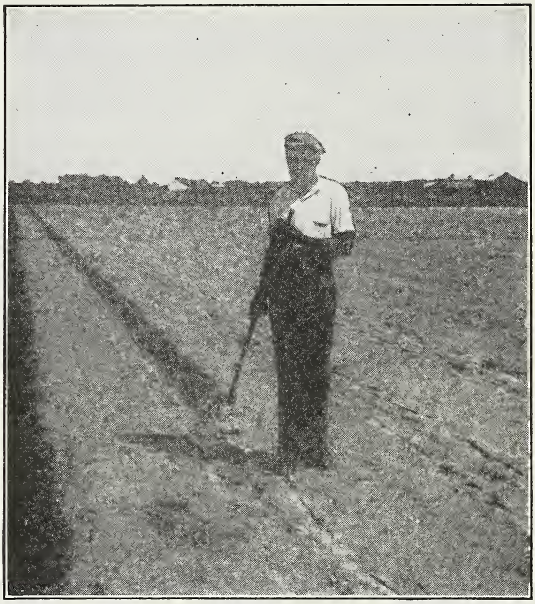

FIGURE 5.—Lettuce cultivator, which is often used to mix the fertilizer with the surface soil in the production of beans in central Florida.

Fertilizers most generally used for beans are 5–7–5, 5–5–5, or 5–8–5. Cottonseed meal, castor-bean meal, and superphosphate are used and applied broadcast by many growers. From 1,200 to 1,500 pounds per acre of a mixed fertilizer is generally applied in two applications, half before planting and half 2 or 3 weeks after the plants are up. Frequently nitrogen and potash are used in small quantities as a later side dressing.

PREVIOUS INVESTIGATIONS

Considerable injury to germination of bean seed and to young bean plants has occurred in the Florida truck belt, and has been attributed to the fertilizer used. This injury has occurred most frequently in periods of light rainfall and where irrigation was delayed. It has been observed that injury was more frequent and severe when the fertilizers used contained principally inorganic or synthetic salts. Injury has not been so apparent when fertilizers contained nitrogen from vegetable or animal sources.

Investigations (*3, 9, 10*)[2] by the United States Department of Agriculture with potatoes and cotton have indicated that proper placement of fertilizers is important in eliminating injury to the seed or young seedlings and in securing the greatest returns from fertilizers. Placement with respect to the seed appears to be a factor of considerable importance in the efficient use of fertilizers for snap beans, especially on sandy soils. The importance of proper placement of fertilizers is indicated by studies made over a period of years by various investigators. The earlier studies were made in greenhouses, few if any being conducted in the field to the maturity of the crop. Sigmund (*20*), Claudel and Crochetelle (*6*), Slosson (*21, 22*), Buffum (*4, 5*), Stewart (*23*), Prunet (*19*), and others as early as 1890 published results of experiments showing the effects of various chemicals and fertilizer materials on the germination and early growth of various seeds and seedlings. Claudel and Crochetelle found that in sand moistened with a 0.2-percent solution of sodium nitrate bean seed did not germinate. Like results were obtained with ammonium sulphate. Superphosphate in 9 parts per 1,000 of water was injurious. Various forms of potash had equally depressing effects.

Later, Hicks (*14*), Berthault (*2*), Harris (*12*), Allison (*1*), and others made similar studies. Hicks found that injury to germination was greater when the fertilizer was placed in direct contact with the seed than when it was mixed with the surface soil. Injury was also greatest between the time the seedling emerged from the seed coat and the time it emerged from the soil. Harris found greater injury to germination when the moisture content of the soil was low than when it was relatively high. Allison found that injury was much more severe on sandy than on loam or clay soils; only one-tenth as heavy an application of fertilizer was necessary to cause injury on light soils equal to that on the loams and clays. There was little or no difference when the fertilizer was placed above, in contact with, or below the seed, or mixed with all the soil in the tumblers in which the tests were made.

Coe (7) found that 25 pounds per acre of ammonium phosphate, analyzing 12 percent nitrogen and 48 percent phosphoric acid, added to Penn loam under greenhouse conditions, depressed the germination of soybeans when placed in contact with the seed, and that no plants appeared with applications of 100 pounds per acre or more, while placement of fertilizers 0.5 to 1 inch to each side of the seed at rates from 25 to 300 pounds per acre did not materially affect germination. The apparent limit of fertilizer tolerance for the germination of soybeans was lower than that for corn, oats, barley, or wheat.

Truog and his coworkers (*24*) in greenhouse studies have shown that 3–18–4 commercial fertilizer applied at the rate of 500 pounds per acre on Plainfield sand has a very marked retarding effect on germination of soybeans and navy beans when placed in contact with the seed, but only a slight effect when placed 0.5 inch above or below the seed.

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[2] Italic numbers in parenthesis refer to Literature Cited, p. 41.

Millar and Mitchell (*18*) studied the influence of placement of fertilizers on white beans in the greenhouse on both Hillsdale sandy loam and Brookston loam. When 20 pounds per acre of treble superphosphate was placed in a band 1.5 inches wide in contact with the seed on sandy loam soil there was a slight decrease in germination, while 30 pounds per acre reduced germination 45 percent. Reduction in germination became significant when monocalcium phosphate was applied at the rate of 30 pounds or more per acre, and when 3–12–4 mixture was applied at the rate of 160 pounds per acre. Superphosphate applied at the rate of 100 pounds per acre in contact with the seed did not materially reduce germination, but when used at the rate of 350 pounds per acre only 80 percent of the plants appeared above ground.

On the loam soil, deterrent effects of the fertilizers were not so marked. With the fertilizer placed 0.5 inch above the seed on the sandy loam, Millar and Mitchell observed that 25 pounds per acre of treble superphosphate materially reduced the stand, and no plants appeared with 100 pounds or more per acre. Four hundred pounds per acre of 16-percent superphosphate placed above the seed did not affect germination. Three hundred and fifty pounds per acre of treble superphosphate mixed with the soil to a depth of 2 inches caused no decrease in germination but 700 pounds per acre inhibited germination.

SCOPE OF EXPERIMENTS

Ten field experiments on machine placement of fertilizer with green or snap beans were conducted in the fall seasons of 1931, 1932, and 1933, four experiments being conducted in each of the first 2 years and two in 1933. Seven of these experiments were located on Leon fine sand and three on St. John's fine sand. One experiment each year was located on the latter soil type.

SOIL TYPES

The Leon fine sand to a depth of 12 to 24 inches is typically a light-gray to almost white fine sand which becomes medium at greater depths. It is dark gray in color when wet, contains little organic matter, and is rather compact. Below the surface soil of the Leon fine sand is a hardpan stratum varying in thickness from 4 to 6 inches, consisting of a dense, compact layer of rusty brown to almost black fine sand high in organic matter. It is fairly impervious and may prevent the capillary rise of moisture during periods of drought. The lower subsoil is a yellowish- to brownish-gray fine sand. There are 149,888 acres (*11*) of the Leon fine sand soil type in Orange County.

The St. John's fine sand in its typical development has a surface soil of dark-gray to black, rather friable fine sand 8 to 10 inches deep. In uncultivated areas the surface soil appears moderately compact, but it becomes looser with cultivation. This is true also of the Leon fine sand. The St. John's type generally contains more organic matter than the Leon, as shown in table 1. This soil type is underlain by a compact, hardpan-like stratum of dark-brown to almost black fine sand which varies in thickness from 4 to 8 inches, this characteristic being outstanding on the areas used in these experiments. This layer is high in organic matter, hard and compact in dry weather but softens when wet. Roots penetrate it with difficulty, and during droughts it may prevent the rise of moisture from below. The subsoil is similar to that of the Leon fine sand. The St. John's fine sand is adapted to the same type of agriculture as the Leon fine sand, and the two types are used principally for the production of beans.

TABLE 1.—*Characteristics of soils used in fertilizer-placement experiments with snap beans near Winter Garden, Fla.*[1]

Experiment no.	Date planted	Type of soil	Soil moisture 0 to 6 inches[2]	pH values at depth of—			Volatile matter at depth of—			Total nitrogen at depth of—		
				0 to 6 inches[2]	6 to 12 inches	12 to 15 inches	0 to 6 inches[2]	6 to 12 inches	12 to 15 inches	0 to 6 inches[2]	6 to 12 inches	12 to 15 inches
			Pct.				*Pct.*	*Pct.*	*Pct.*	*Pct*	*Pct.*	*Pct.*
1	Sept. 17, 1931	Leon fine sand	13.3	4.640	4.865	------	1.751	0.844	------	0.0446	0.0252	------
2	Sept. 18, 1931	do	10.2	5.270	5.912	------	1.744	1.265	------	.0527	.0238	------
3	Sept. 23, 1931	do	15.8	5.210	5.585	------	2.935	1.423	------	.0552	.0263	------
4	Sept. 22, 1931	St. John's fine sand.	11.5	6.185	6.830	------	2.412	1.694	------	.0554	.0237	------
5	Sept. 15, 1932	Leon fine sand	16.1	5.43	5.39	5.57	1.995	1.195	1.170	.056	.034	0.022
6	Sept. 13, 1932	do	17.95	6.98	7.05	6.68	2.832	2.162	1.304	.072	.044	.028
7	Sept. 10, 1932	do	13.6	5.67	5.37	5.88	2.181	1.594	.748	.062	.031	.010
8	Sept. 12, 1932	St. John's fine sand.	17.6	6.54	6.86	6.60	2.130	1.819	.665	.072	.044	.028
9	Sept. 21, 1933	Leon fine sand	11.9	6.245	6.005	5.82	------	------	------	.0507	.0447	------
10	Sept. 20, 1933	St. John's fine sand.	15.4	6.845	7.115	7.045	------	------	------	.0624	.0492	.0703

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[1] Chemical analysis of the soils was made by A. E. Hughes, Soil Fertility Division, Bureau of Plant Industry.

[2] 0 to 7 inches in experiments 1, 2, and 4.

FERTILIZERS

Both ordinary and double-strength fertilizer mixtures were used in the machine-placement fertilizer experiments. The materials used in the fertilizer mixtures are given in table 2.

TABLE 2.—*Composition of fertilizers used in the machine-placement fertilizer experiments on Leon and St. John's fine sand, Winter Garden, Fla.*

Material	Analysis			Pounds per ton of 5–7–5 or per 1,000 pounds of 10–14–10		
	NH_3	P_2O_5	K_2O	5–7–5[1] (one half organic)	10–14–10[1]	5–7–5[1] (inorganic)
	Percent	*Percent*	*Percent*			
Sodium nitrate	18			139	276	278
Ammonium sulphate	25			100	200	200
Tankage	10	3		250		
Fish scrap	10	6		250		
Superphosphate		18		653		778
Sulphate of potash			48	208	416	208
Ammo-Phos	13	46			608	
Urea	55.9				38	
Sand				400	462	536

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[1] Fertilizer constituents are given in the order, ammonia, phosphoric acid, and potash. The fertilizer analyses are on the ammonia basis as this was common practice when the experiments were in operation.

Two fertilizers, a 5–7–5 and a 10–14–10, were used in the four experiments conducted in 1931. The nitrogen in the 5–7–5 fertilizer was derived one-half from inorganic sources and one-half from organic sources. This fertilizer was in good physical condition, and drilled well. Some of the materials used in the 10–14–10 fertilizer differ from those used in the 5–7–5, they being selected to produce a mixture of high concentration. A direct comparison of the fertilizers is not the object of this study which is concerned with the effect of placement of each of the fertilizers. The 10–14–10 mixture absorbed moisture in wet weather after standing several days. In the six tests in 1932 and 1933, two 5–7–5 fertilizers were used, one in which the nitrogen was derived one-half from inorganic and one-half from organic sources, and in the other the nitrogen was derived entirely from inorganic sources. The latter mixture absorbed moisture slightly.

SEED

The Bountiful variety of beans was planted in each experiment. The seed was supplied by local dealers from stocks imported from the Midwestern States.

PLACEMENT MACHINES

In a fertilizer-placement experiment, obviously a number of conditions in addition to the relative positions of fertilizer and seed must be accurately controlled. The amounts and distribution of seed and of fertilizer, width of fertilizer bands, depth and compactness of soil over the seed, general level of the final seedbed, and other seedbed conditions must be uniform throughout the experiment. This is especially true when the variations in fertilizer placement are relatively small and differences in the effect on germination of the seed, early plant growth, and time of maturity are anticipated.

It was recognized that the only practical method of controlling the various seedbed conditions of a fertilizer-placement experiment conducted in the field on an extensive scale is to use a machine that simultaneously plants the seed, places the fertilizer, and accomplishes all necessary soil manipulations. In order to meet the varied requirements of the tests under different farm practices and soil conditions, the machine must have more attachments, adjustments, and refined controls than is ordinarily required on standard farm machines. Such a machine has been developed by the Bureau of Agricultural Engineering. The general features of the machine are illustrated in figure 6. The machine is of the four-wheel type, which permits rigid construction and arrangement of attachments for accurate relative placements of fertilizer and seed. It is drawn by two horses.

The machine was equipped with a standard sight-feed, slanting-plate, cell-type seed hopper. Provision was made for mounting the hopper at either the front or the rear of the machine. The quantities of seed sown on the various plats did not differ materially, the maximum variation being less than 1 percent.

The fertilizer-dispensing mechanism is of the top-delivery rotating-cylinder type, the construction and performance of which has been previously described (*8, 10, 17*). The hopper is equipped with four delivery openings and tubes. The tubes are flexible and their length and point of attachment are such that fertilizer can be directed to any desired point on the machine. Fertilizer can be delivered through one or more tubes simultaneously and in varying proportions. The type of dispensing mechanism is such that delivery rate is little affected by changes in the physical properties of the fertilizer and in operating conditions, but the fertilizer needs to be thoroughly settled in the hopper. The dispensing action of the hopper is positive, and desired rates of application are obtained by gear and sprocket combinations.

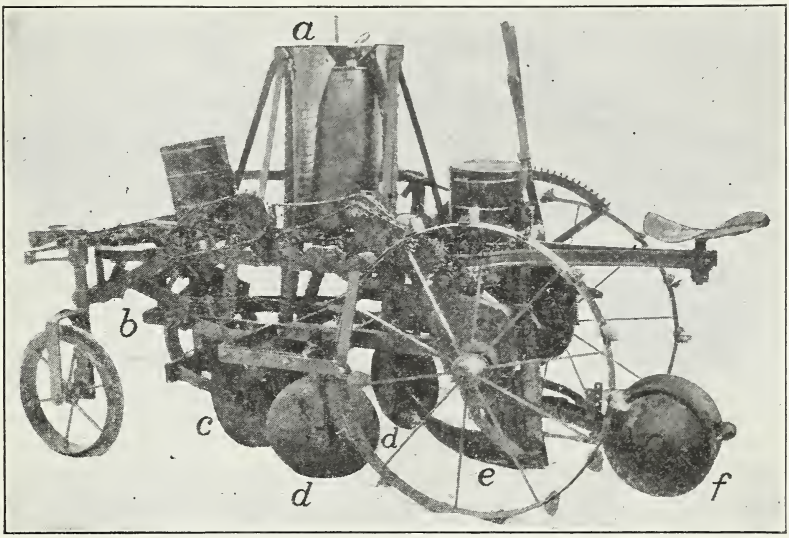

FIGURE 6.—Special combination planter and fertilizer distributor built under the general specifications of the Bureau of Agriculturel Engineering for fertilizer-placement experiments with truck crops; (*a*) Top-delivery fertilizer hopper; (*b*) subframe for holding the soil-working tools; (*c*) single-disk furrow openers for placing the fertilizer at the sides of the seed; (*d*) bedding disks; (*e*) seed shoe; (*f*) press wheel.

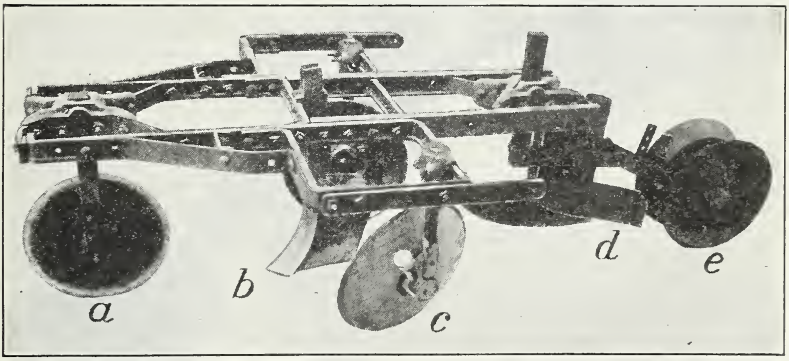

FIGURE 7.—Subframe of distributor equipped for placing fertilizer in a band under the seed: *a*, Rolling colter; *b*, special shovel with shields attached, for opening fertilizer furrow; *c*, bedding disks; *d*, seed shoe with wings for regulating the depth of furrow; *e*, covering wheel.

The operating principle of the dispensing mechanism insures uniform distribution of a fertilizer in good drilling condition. Previous tests with this type of hopper indicate that the fertilizer is distributed along the row with a coefficient of variation of approximately 9 percent, based on 1-foot intervals, and the average deviation in application rates for the six rows of each test was less than 1 percent.

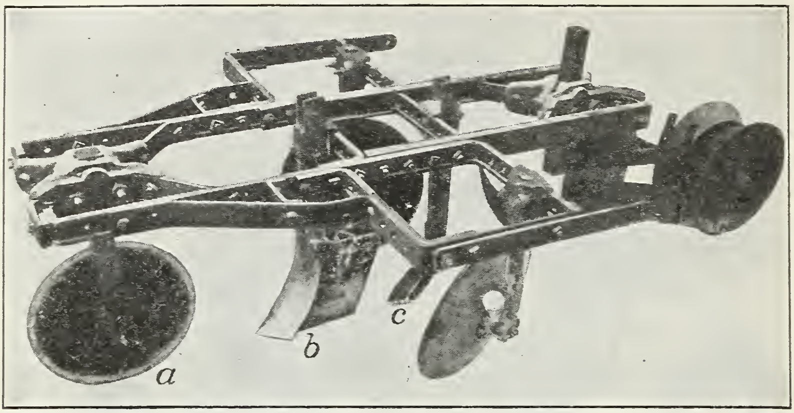

FIGURE 8.—Subframe of distributor equipped to mix the fertilizer with the soil under the seed: *a*, Rolling colter; *b*, furrowing shovel; *c*, special mixing shovel.

All soil-working tools are mounted on the subframe (fig. 6, *b*) which can be raised or lowered without change of inclination. The seed-covering wheel is free to exert constant pressure, and it is the only tool not held rigidly to the frame. Thus the soil-working tools, including those for placing the fertilizer and the seed, are carried up and down without change of their relative positions. Adjustments of wide range for individual tools are provided to obtain desired ferti-

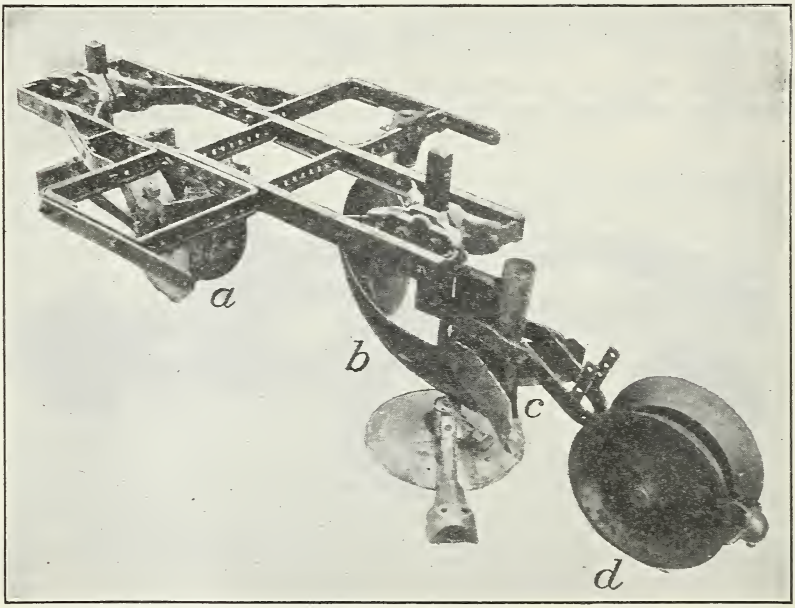

FIGURE 9.—Subframe of distributor equipped to place the fertilizer in a narrow band at each side of the row: *a*, A pair of single disks for opening 2 fertilizer furrows; *b*, bedding disks; *c*, seed shoe; *d*, press wheel.

lizer placements and to meet the various seedbed requirements as shown in figures 7, 8, and 9. To guard against changes in relative positions of the fertilizer and the seed resulting from angling of the machine on lateral slopes, reasonably level land was selected for the experiments.

In the experiments to be made, various placements of the fertilizer relative to the seed were desired. To obtain the placements on the surface of the ground over the seed, the seed hopper and press wheel were mounted at the front of the machine and the fertilizer tubes were carried to the rear to deliver the fertilizer after the seed had been planted and covered. For the other placements, the seed hopper was mounted at the rear of the machine. For the placements in a band under the seed, shovels were used to open furrows of the proper depth and width, the shovels being so set that a furrow with a flat bottom would result. Attached to these shovels were shields to keep out the soil (fig. 7, *b*) and guide the fertilizer into a band of uniform width. Back of these shovels a pair of bedding disks, *c*, was used to fill the furrows and cover the fertilizer with an excess of soil; the seed shoe, *d*, of the sword or runner type operating in the rear of the bedding disks was usually equipped with a pair of wings or scrapers with which planting depth was controlled. The wings lowered the surface of the seedbed to a constant height above the level of the seed. Thus uniform coverage of the seed by the press wheel was insured.

In order to mix the fertilizer with the soil under the seed, the fertilizer was first deposited in a band by the use of the above-described shielded shovel. A small mixing shovel (fig. 8, *a*) followed, operating at a slightly greater depth, and mixed the fertilizer with the soil.

For placements to the sides of the seed a pair of single disks (fig. 9, *a*) was used to open the furrows for the fertilizer. The fertilizer tubes were attached at the rear of the disks, to direct the fertilizer to the bottom of the furrow. The fertilizer was thus placed in a narrow band at each side of the row. The disks were adjustable both laterally and vertically, for obtaining various side placements.

Trash and crop residue turned under in plowing was disturbed by the fertilizer furrowing shovels when operating at the depth required to place the fertilizer 3 inches under the seed. Difficulties in this respect were largely eliminated by mounting a rolling colter (fig. 7, *a*) ahead of the shovel. Disk furrow openers used for the side placements cut through the trash without difficulty. The disks also operated with considerably less draft than the 2-inch and 4-inch shovels in placing the fertilizer at the same depth.

Applications of fertilizer in a band at the side of the row several weeks after planting were made with a one-row horse-drawn walking-type distributor (fig. 10) equipped with the top-delivery type of hopper previously mentioned. A furrow of uniform depth was opened for the fertilizer, and a covering shovel returned the soil to the furrow.

EXPERIMENT PLOTS

Each experiment comprised about 1 acre of land which was divided into six blocks of equal size and shape, and all treatments or placements were systematically arranged in each block. The six plots of each placement were thus well distributed over the field.

Each plot consisted of a single row, usually 130 feet in length. The rows were spaced 30 inches apart except in experiment no. 1

where the spacing was 35 inches. The crop records were taken from 100 feet of row except in experiment no. 8 where they were taken from 80 feet of row. Ten feet at each end of the row was disregarded in order to avoid any irregularities of fertilizer application that might have resulted from starting or stopping the machine. Where data were recorded on only 80 feet of row, the results were converted in the tables to the basis of 100 feet for convenience in making comparisons.

In two tests of each experiment no fertilizer was applied at time of planting, in order to provide a check on the viability of the seed. The soil under the seed was disturbed for one of these tests and not disturbed for the other. Thus a more direct comparison with the fertilizer placement tests is possible, because the soil was disturbed in placing the fertilizer under the seed but not disturbed for the side placements. These tests, however, received the standard initial application of fertilizer approximately 1 week after planting, in accordance with a practice sometimes followed by the growers.

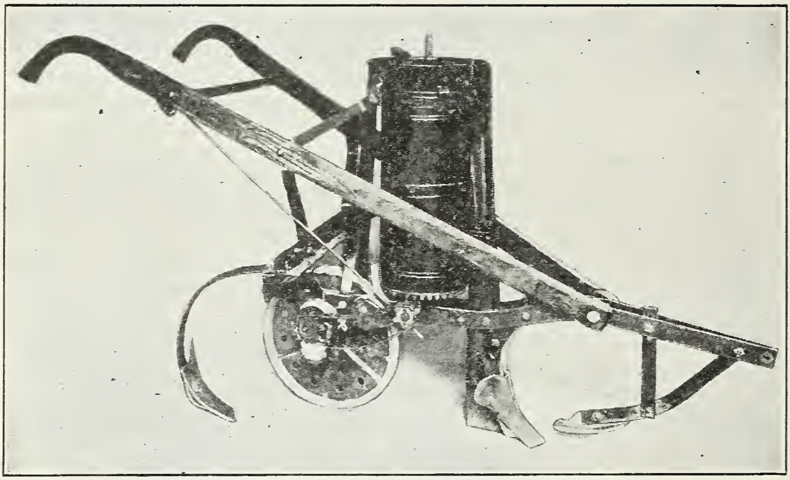

FIGURE 10.—One-row distributor used to side dress the fertilizer in a furrow close to the row.

Soil samples for determinations of moisture, pH values, total nitrogen, and volatile matter were taken at each location immediately before planting operations began. The results of these determinations are given in table 1.

SOIL MOISTURE AND RAINFALL

Soil moisture at time of planting and rainfall for the periods during which the experiments were in progress are given in tables 1 and 3, respectively. For convenience in picturing the progress of the experiments with relation to rainfall, table 3 shows also the dates of planting, early stand counts, fertilizer side dressings, and the various pickings in harvesting the crop. The only rainfall records available in 1931 were those obtained at Orlando, Fla., approximately 12 miles from the experiments. In considering these records for 1931 it should be borne in mind that many rains in this section are characteristically local, consisting of "tropical" showers, and that actual rainfall at the locations of the experiments may differ slightly from that shown. In 1932 a rain gage was set up at experiment no. 8, and in 1933 at experiment no. 10, which were located within a mile of the other experiments.

The average monthly rainfall at Orlando for September, October, and November for the 24 years 1910 to 1933, inclusive, is given in table 4 together with the records for 1931, 1932, and 1933. It will be observed that the rainfall during the entire bean-growing season was considerably below normal in 1931, and was extremely low during September and October of 1932. Favorable moisture conditions prevailed during the germination period of September 1933. The rainfall for each of the months of September and October 1932 was nearly the lowest recorded in 24 years. The rainfall of 14.10 inches for September 1933 was the highest on record; 11.33 inches fell on September 5 and 6.

TABLE NO. 3.—*Rainfall and times of operations in connection with fertilizer placement experiments with snap beans at Orlando and Winter Garden, Fla., 1931–33* [1]

Date	1931					1932						1933			
	Rainfall, Orlando	Operations for experiment nos.				Rainfall		Operations for experiment nos.				Rainfall		Operations for experiment nos.	
		1	2	3	4	Orlando	Winter Garden	5	6	7	8	Orlando	Winter Garden	9	10
	Inches					*Inches*	*Inches*					*Inches*	*Inches*		
Sept. 10										P					
11							0.53								
12	0.18					0.40	.02				P				
13							.60		P						
14	.63					.55	.41								
15	.07					1.43	.43	P		G1					
16	(2)														
17		P								G2	G1				
18			P												
19									G1	(*)	G2		0.02		
20								G1	G2		(*)	0.68			P
21														P	
22		G1			P		.07	G2				1.44	.16		
23	.44		G1	P					(*)						
24	.07	G2*	G2*							G3					
25	(2)						.44								G1
26						.12	.37	(*)			G3	.09		G1	
27	.23				G1		(2)		G3						G2*
28				G1										G2*	
29	.11				G2*			G3					.01		
30	.14			G2*									.04		
Oct. 1		G3													
2	.07		G3												
3						.21				SD		.30	.28		
4	.18							SD			SD		.16		G3
5	.01			G3	G3		.10					1.36	.50	G3	
6	.45	SD				.55						.35	.20		
7	.08												(3)		
8	(2)														
9	.07														SD
10														SD	
11							(2)								
12			SD												
13	.13			SD	SD				SD						
14	.07														
15	.02														
16	(2)						.26					.18			
17						.25									
19	.15														
20												.25			
21	(2)											2.75			

[1] The various symbols indicate the following operations: P=test planted; G1=first germination count; G2=second germination count; G3=third germination count; *=date of side dressing checks first time; SD=date of side dressing entire test; Y1, Y2, Y3, Y4, and Y5=respectively, first, second, third, fourth, and fifth pickings.

(2) Trace.

(3) No record subsequent to this date.

Table No. 3.—*Rainfall and times of operations in connection with fertilizer placement experiments with snap beans at Orlando and Winter Garden, Fla., 1931–33*—Continued

Date	1931					1932						1933			
	Rainfall, Orlando	Operations for experiment nos.				Rainfall		Operations for experiment nos.				Rainfall		Operations for experiment nos.	
		1	2	3	4	Orlando	Winter Garden	5	6	7	8	Orlando	Winter Garden	9	10
	Inches					*Inches*	*Inches*					*Inches*	*Inches*		
Oct. 23										Y1		.65			
25												.33			
26						.34					Y1				
27						.13	.03			Y2					
29	.07								Y1		Y2				
31		Y1						Y1							
Nov. 1						.24	.28		Y2	Y3					
2							.13				Y3				
3			Y1												
4						.21	1.57								
5		Y2				1.77		Y2	Y3	Y4					
6			Y2									.54		Y1	Y1
7						.53	.24				Y4				
8						.97	.75		Y4						
9					Y1		1.14	Y3							
10		Y3	Y3	Y1			(3)							Y2	
13				Y2	Y2										Y2
14		Y4	Y4												
16				Y3	Y3										
17														Y3	
19				Y4	Y4										
20	.09														
22	.03														Y3
23	.01				Y5										
25														Y4	
26												1.39			
27															Y4

[3] No record subsequent to this date.

Table 4.—*Monthly rainfall for September, October, and November at Orlando, Fla., 1910–33*

Month	Average 1910–33	1931	1932	1933
	Inches	*Inches*	*Inches*	*Inches*
September	6.69	4.92	2.67	14.10
October	4.80	1.68	.95	3.84
November	1.96	.19	4.93	1.72

The soil-moisture conditions at and immediately following planting are described more fully for each experiment under the following discussion of general conditions.

GENERAL CONDITIONS OF EXPERIMENTS

Experiment no. 1, 1931, on Leon fine sand included a ridge somewhat higher and dryer than the general topography of the field. The area was tile drained and equipped for subirrigation. The plowing was not deep and complete coverage of plant residue was not obtained. The furrowing tools on the machine used in planting brought more of this debris to the surface. The soil was dry at planting and for a few days thereafter. The whole growing season was dry, the yields being decreased by lack of moisture. The irrigation system was not employed.

The area for experiment no. 2, 1931, on Leon fine sand was also tile drained and equipped for subirrigation, and the system was used during the season to supply needed moisture. The land was well plowed, but had been disked and dragged afterward to such an extent that the soil was very dry to a depth of several inches at time of planting. As a result of this dry topsoil, stands were poor as compared to those obtained at other locations. Sufficient irrigation was applied later, however, to alleviate this condition.

In experiment no. 3, 1931, on Leon fine sand, rains immediately preceded planting and a shower fell the day of planting, hence moisture conditions were highly favorable. The area was tile drained and subirrigated. Sufficient moisture was applied by irrigation during the growing season to avoid any adverse effects of the dry season. The land was well prepared and in good condition for planting.

For experiment no. 4, 1931, on St. John's fine sand, the soil contained adequate moisture at planting and throughout the season. The area was tile drained and subirrigated. Some general damage was caused by leaf roller worms and leaf hoppers, but not enough to invalidate the results.

The area for experiment no. 5, 1932, on Leon fine sand was in the same field and adjacent to the location of experiment no. 1, 1931, but did not include the ridge mentioned. The land was in good condition for planting, being well plowed and moist. There was no rain until the seventh day after planting, and then only 0.07 inch, and on the tenth day there was 0.44 inch of rain. This dry period caused marked differences in the rate and amount of germination. The area was tile drained and arranged for subirrigation, but although the season was too dry for maximum yields the land was not irrigated.

On experiment no. 6, 1932, on Leon fine sand, daily rains for 2 days preceding and 2 days following the planting insured adequate moisture. A tile-drainage and subirrigation system underlay the experiment plot, and the area was well irrigated during the whole season. The land was well prepared but some crop residue was disturbed by the soil-working tools.

The area for experiment no. 7, 1932, on Leon fine sand was tile drained but not equipped for irrigation. Sufficient rain fell, however, to carry the crop through without serious damage. Crop debris was disturbed by the planting operations. A heavy infestation of leaf hoppers caused general injury before the application of insecticides was begun. Three blocks of the experiment were abandoned before the beans were harvested because of serious nematode injury. There was little or no damage on the three remaining blocks, on which the data are based.

The area used in experiment no. 8, 1932, on St. John's fine sand comprised an enlarged section of that used in experiment no. 4 in 1931. It was tiled for drainage and subirrigation. Yields were reduced somewhat by general leaf hopper injury before insecticides were applied. Crop residue partially plowed under was disturbed by the machine in the planting operations.

The area used in experiment no. 9, 1933, on Leon fine sand was tile drained and subirrigated. The growing season was dry but irrigation prevented injury to the crop. At planting, the topsoil was dry to a depth of about 3 inches, but the soil underneath was moist. Germination in those tests where the soil was not disturbed below the seed was delayed slightly as the seed were deposited in dry soil. In those tests where the moist soil from the lower strata was brought to the surface and surrounded the seed, there was no apparent delay to germination.

The area for experiment no. 10, 1933, on St. John's fine sand was in the same field and adjacent to the area used in experiments nos. 4 and 8. It was tile drained and subirrigated. The soil was slightly dryer than desirable at planting but a light rain 2 days after planting insured a good stand where injurious effects were avoided by advantageous placement of the fertilizer. Considerable crop residue was brought to the surface on those plots where the fertilizer was placed 3 inches under the seed.

EFFECT OF FERTILIZER PLACEMENT ON SEED GERMINATION

In considering the influence of fertilizer materials and placement of fertilizers on germination and stand of beans, consideration should be given to the solubility of fertilizer salts in soil moisture and the movement of the solution in soils. The movement of the soil solution in soils varies with their physical composition and possibly their chemical composition. The downward movement occurs readily but in most instances there is little lateral movement of salts in soils. The concentration of fertilizer salts, through the movement of soil moisture, may become sufficiently great in the surface soil and close enough to the roots of the plants to be injurious to seeds or the young plants. In considering the early effects of fertilizer applied in various positions with respect to the seed, consideration must be given to the amount of soil moisture at time of fertilizer applications, the amount and distribution of rainfall, the type of soil, and the amount and solubility of the fertilizer materials.

These factors have been studied by a number of investigators including the following: Harris (*13*), McCool and Wheeting (*16*), McCool and Millar (*15*), Wheeting (*26*), Coe (*7*), Van Alstine (*25*), Berthault (*2*), Claudel and Crochetelle (*6*), and Cumings, Mehring, Skinner, and Sachs (*10*).

Counts of plants which had emerged above ground on three different dates during a period of about 2 weeks following planting were considered as indicating the influence on germination of fertilizers placed in various positions with respect to the bean seed. The first and third stand counts for the various treatments, the description of the fertilizer placements, and other essential information are given in table 5. The first and last stand counts seem sufficient to show the effect on germination, therefore the table includes only these. The dates of planting, fertilizer applications, and crop records are shown together with the daily rainfall in table 3 previously discussed.

TABLE 5.—*Plants above ground per 100 feet of row and yield of green beans per acre for various placements of fertilizer at Winter Garden, Fla., 1931–33*

5-7-5 (ONE-HALF N FROM ORGANIC SOURCES) FERTILIZER 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING

Placement of first application of fertilizer	Experiment no. 1 planted Sept. 17, 1931, Leon fine sand							Experiment no. 2 planted Sept. 18, 1931, Leon fine sand						
	Plants per 100 feet of row			Yield per acre [1]				Plants per 100 fect of row			Yield per acre [2]			
	Sept. 22	Sept. 24	Oct. 11	First picking Oct. 31	Second picking Nov. 5	Sum, first and second picking	Total	Sept. 23	Sept. 25	Oct. 2	First picking Nov. 1	Second picking Nov. 6	Sum, first and second picking	Total
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No fertilizer at planting, soil disturbed below seed [3]	202	263	284	1, 205	774	1, 979	3, 162	191	217	224	1, 945	1, 240	3, 185	5, 239
No fertilizer at planting, soil undisturbed below seed [3]	202	329	354	692	846	1, 538	2, 386	156	188	198	1, 598	1, 193	2, 791	4, 550
Average	202	296	319	948	810	1, 758	2, 774	174	202	211	1, 771	1, 217	2, 988	4, 894
3.5-inch band on surface of ground over seed	183	280	305	1, 415	997	2, 412	3, 786	98	156	168	1, 756	1, 072	2, 828	4, 926
In contact with seed [4]	0	0						0	0					
1.75-inch band 1 inch under seed	37	148	221	901	1, 347	2, 248	3, 933	19	48	92	555	721	1, 276	3, 319
1.75-inch band 3 inches under seed	222	287	308	1, 818	1, 362	3, 180	4, 803	148	183	223	2, 620	1, 173	3, 793	6, 670
3.5-inch band 1 inch under seed	7	31	77	132	452	584	1, 402	76	131	160	1, 704	1, 161	2, 865	5, 672
3.5-inch band 3 inches under seed	200	253	290	1, 616	1, 018	2, 634	4, 283	145	183	204	2, 568	1, 595	4, 163	6, 613
Mixed with soil under seed to depth of 3 inches	85	207	282	978	1, 345	2, 323	4, 047	43	89	135	1, 195	1, 373	2, 568	5, 280
Narrow band 2 inches to each side and 1½ inches below seed	257	339	347	1, 500	1, 019	2, 519	4, 050	176	197	203	3, 216	1, 400	4, 616	6, 795
Narrow band 4 inches to each side and 1½ inches below seed	192	313	332	1, 271	1, 172	2, 443	3, 743	159	181	185	3, 269	1, 302	4, 571	7, 081
10–14–10 FERTILIZER 350 POUNDS PER ACRE AT PLANTING, 350 POUNDS PER ACRE SIDE DRESSING 3 WEEKS AFTER PLANTING														
3.5-inch band on surface of ground over seed	109	337	346	970	1, 304	2, 274	3, 778	123	182	188	2, 446	1, 259	3, 705	6, 080
In contact with seed [4]	0	0						0	0					
1.75-inch band 1 inch under seed	5	53	162	93	587	680	1, 898	17	49	81	820	864	1, 684	3, 643
3.5-inch band 1 inch under seed	8	63	206	85	534	619	2, 051	58	80	107	850	990	1, 840	3, 842
Mixed with soil under seed to depth of 3 inches	(5)							45	83	116	833	1, 262	2, 095	4, 491
Narrow band 2 inches to each side and 1½ inches below seed	225	323	354	1, 182	1, 262	2, 444	3, 937	156	180	184	3, 071	1, 338	4, 409	6, 541
Narrow band 3 inches to each side and 1½ inches below seed	242	321	344	1, 473	1, 107	2, 580	4, 016							

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[1] 3 pickings 4 to 6 days apart were made. [2] 4 pickings 3 to 5 days apart.

[3] Fertilizer applied as side dressings, in furrow 2½ inches deep and 4 inches to one side of plants, 1 and 3 weeks after planting, 700 pounds per acre each application.

[4] Rows replanted 1 week after original planting, no yields recorded. [5] Test not included in experiment no. 1.

TABLE 5.—*Plants above ground per 100 feet of row and yield of green beans per acre for various placements of fertilizer at Winter Garden, Fla., 1931–33*—Continued

5-7-5 (ONE-HALF N FROM ORGANIC SOURCES) FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING

Placement of first application of fertilizer	Experiment no. 3 planted Sept. 23, 1931, Leon fine sand							Experiment no. 4 planted Sept. 22, 1931, St. John's fine sand						
	Plants per 100 feet of row			Yield per acre [6]				Plants per 100 feet of row			Yield per acre [7]			
	Sept. 28	Sept. 30	Oct. 5	First picking Nov. 10	Second picking Nov. 13	Sum, first and second pickings	Total	Sept. 27	Sept. 29	Oct. 5	First picking Nov. 9	Second picking Nov. 13	Sum, first and second pickings	Total
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No fertilizer at planting, soil disturbed under seed [8]	164	291	295	3, 285	1, 308	4, 593	6, 730	154	269	281	3, 802	1, 476	5, 278	7, 813
No fertilizer at planting, soil undisturbed under seed [8]	241	325	324	2, 623	1, 872	4, 495	6, 643	144	245	263	3, 997	1, 240	5, 237	8, 098
Average	202	308	310	2, 954	1, 590	4, 544	6, 687	149	257	272	3, 900	1, 358	5, 258	7, 955
3.5-inch band on surface of ground over seed	153	335	348	2, 549	2, 731	5, 280	7, 313	79	240	271	3, 709	1, 519	5, 228	8, 524
In contact with seed	0	(9)	------	------	------	------	------	0	(9)	------	------	------	------	------
1.75-inch band 1 inch under seed	21	138	236	2, 183	1, 600	3, 783	6, 915	33	151	223	3, 347	1, 728	5, 075	8, 564
1.75-inch band 3 inches under seed	216	280	276	3, 364	1, 792	5, 156	7, 754	203	254	283	4, 691	1, 529	6, 220	9, 535
3.5-inch band 1 inch under seed	58	201	264	2, 484	1, 885	4, 369	6, 945	15	100	200	2, 286	1, 763	4, 049	7, 882
3.5-inch band 3 inches under seed	240	328	325	3, 256	1, 508	4, 764	7, 250	205	263	273	4, 366	1, 830	6, 196	9, 327
Mixed with soil to depth of 3 inches under seed	66	208	280	2, 402	1, 769	4, 171	7, 118	60	198	241	2, 879	2, 058	4, 937	8, 432
Narrow band 2 inches to each side and 1½ inches below seed	244	310	316	3, 410	1, 353	4, 763	7, 183	191	283	299	4, 502	1, 409	5, 911	8, 931
Narrow band 4 inches to each side and 1½ inches below seed	226	350	351	3, 191	1, 442	4, 633	6, 497	181	264	281	4, 469	1, 484	5, 953	9, 135

10–14–10 FERTILIZER, 350 POUNDS PER ACRE AT PLANTING, 350 POUNDS AS SIDE DRESSING 3 WEEKS AFTER PLANTING

3.5-inch band on surface of ground over seed	50	269	346	2, 042	1, 936	3, 978	6, 410	15	148	220	3, 175	1, 762	4, 937	8, 130
In contact with seed	0	(9)						0	(9)					
1.75-inch band 1 inch under seed	10	79	169	1, 358	1, 748	3, 106	5, 864	61	186	240	3, 773	1, 946	5, 719	9, 351
3.5-inch band 1 inch under seed	40	208	299	1, 788	2, 201	3, 989	6, 949	36	175	245	2, 995	1, 927	4, 922	8, 857
Mixed with soil to depth of 3 inches under seed	69	174	249	1, 768	2, 339	4, 107	6, 453	15	90	194	1, 962	1, 916	3, 878	7, 379
Narrow band 2 inches to each side and 1½ inches below seed	268	353	359	3, 299	2, 556	5, 855	8, 427	155	245	263	4, 717	1, 530	6, 247	9, 571

[6] 4 pickings 3 days apart.

[7] 5 pickings 3 to 4 days apart.

[8] Fertilizer applied as side dressings, 700 pounds per acre 1 and 3 weeks after planting, in furrows 2½ inches deep and approximately 4 inches to one side of plants.

[9] Replanted 1 week after original planting, no yields recorded.

Table 5.—*Plants above ground per 100 feet of row and yield of green beans per acre for various placements of fertilizer at Winter Garden, Fla., 1931–33*—Continued

5-7-5 INORGANIC FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING

Placement of first application of fertilizer	Experiment no. 5 planted Sept. 15, 1932, Leon fine sand							E xperiment no. 6 planted Sept. 13, 1932, Leon fine sand						
	Plants per 100 feet of row			Yield per acre [10]				Plants per 100 feet of row			Yield per acre [11]			
	Sept. 20	Sept. 2	Sept. 29	First picking Oct. 31	Second picking Nov. 4	Sum first and second pickings	Total	Sept. 19	Sept. 21	Sept. 27	First picking Oct. 29	Second picking Nov. 1	Sum first and second pickings	Total
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No fertilizer at planting, soil disturbed under seed [12]	217	307	299	1, 771	641	2, 412	2, 682	266	308	321	1, 690	2, 354	4, 044	6, 163
No fertilizer at planting, soil undisturbed under seed [12]	202	304	331	1, 516	450	1, 966	2, 248	242	317	329	1, 762	2, 364	4, 126	6, 313
Average	210	305	315	1, 644	545	2, 189	2, 465	254	312	325	1, 726	2, 359	4, 085	6, 238
3.5-inch band on surface of ground over seed	170	268	266	1, 558	760	2, 318	2, 703	24	224	274	1, 416	2, 213	3, 629	6, 468
1.75-inch band 1 inch under seed	5	42	126	380	723	1, 103	1, 796	217	319	325	1, 922	2, 298	4, 220	6, 862
1.75-inch band 2 inches under seed	----	----	----	----	----	----	----	263	324	317	2, 436	2, 297	4, 733	7, 262
1.75-inch band 3 inches under seed	[13] 60	191	288	2, 070	1, 282	3, 352	4, 591	280	329	326	2, 736	2, 422	5, 158	7, 939
3.5-inch band 1 inch under seed	13	101	263	1, 296	1, 263	2, 559	3, 903	270	322	320	2, 281	2, 145	4, 426	7, 034
3.5-inch band 3 inches under seed	210	292	313	2, 448	1, 037	3, 485	4, 002	276	327	324	2, 561	2, 405	4, 966	7, 546
Mixed with soil to depth of 3 inches under seed	109	245	306	2, 103	1, 359	3, 462	4, 091	258	310	315	2, 167	2, 412	4, 579	7, 076
Narrow band 2 inches to each side and ½ inch below seed	(13)	----	----	----	----	----	----	302	342	335	3, 014	2, 344	5, 358	7, 923
Narrow band 2 inches to each side and 1½ inches below seed	226	314	322	2, 067	826	2, 893	3, 294	311	342	343	2, 966	2, 117	5, 083	7, 681
Narrow band 2 inches to each side and 2½ inches below seed	(13)	----	----	----	----	----	----	298	343	327	2, 981	1, 875	4, 856	7, 576
Narrow band 3 inches to each side and 1½ inches below seed	206	324	322	2, 172	693	2, 866	3, 342	315	366	356	2, 643	2, 398	5, 041	7, 691
Narrow band 4 inches to each side and 1½ inches below seed	200	323	335	1, 981	705	2, 687	2, 980	284	344	333	2, 499	2, 338	4, 837	7, 144
In band 6 inches wide on ground surface, thrown out with 4-inch "scooter", seed planted in resulting furrow	(13)	----	----	----	----	----	----	286	330	319	1, 746	2, 234	3, 980	6, 276
In band 6 inches wide on ground surface, mixed with 5-tooth "scratcher", seed planted below resulting mixture	(13)	----	----	----	----	----	----	297	332	329	1, 641	2, 248	3, 889	6, 208
In band 6 inches wide on ground surface, bedded on 2 inches deep, seed planted in bed	(13)	----	----	----	----	----	----	201	337	336	1, 627	2, 364	3, 991	6, 407

5-7-5 (ONE-HALF N FROM ORGANIC SOURCES) FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING														
In 3.5-inch band on surface of ground over seed	211	280	283	1, 564	617	2, 181	2, 537	49	266	280	1, 843	2, 141	3, 984	6, 734
In 1.75-inch band 1 inch under seed	24	137	259	1, 509	1, 192	2, 701	3, 680	102	293	296	1, 638	2, 500	4, 138	6, 787
In narrow band 2 inches to each side and 1½ inches below seed	254	315	326	2, 551	653	3, 204	3, 603	248	327	315	2, 286	2, 463	4, 749	6, 980
10-14-10 FERTILIZER, 350 POUNDS PER ACRE AT PLANTING, 350 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING														
In 3.5-inch band on surface of ground over seed	199	278	275	1, 073	402	1, 475	1, 763	32	213	255	1, 563	2, 377	3, 940	6, 632
1.75-inch band 1 inch under seed	15	69	172	547	718	1, 265	1, 681	47	195	276	1, 831	2, 140	3, 971	6, 513
3.5-inch band 1 inch under seed	35	156	292	1, 237	913	2, 150	3, 004	172	314	315	2, 215	1, 993	4, 208	7, 285
Mixed with soil to depth of 3 inches under seed	130	238	301	1, 854	920	2, 774	3, 436	221	333	329	2, 495	2, 509	5, 004	7, 804
Narrow band 2 inches to each side and 1½ inches below seed	250	315	321	2, 176	470	2, 646	3, 124	221	332	330	2, 561	2, 424	4, 985	7, 832
In 6-inch band on ground surface, thrown out with 4-inch "scooter", seed planted in resulting furrow	(13)	------	------	------	------	------	------	239	314	311	2, 305	2, 009	4, 314	6, 985
In 6-inch band on ground surface, bedded on 2 inches deep, seed planted in bed	(13)	------	------	------	------	------	------	67	250	291	1, 955	1, 685	3, 640	6, 331

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[10] 3 pickings 5 days apart.

[11] 4 pickings 3 to 4 days apart.

[12] Fertilizer applied as side dressings 1 and 3 weeks after planting, 700 pounds per acre each application, in furrows 2½ inches deep, 4 inches to one side of plants.

[13] Treatment not included.

TABLE 5.—*Plants above ground per 100 feet of row and yield of green beans per acre for various placements of fertilizer at Winter Garden, Fla., 1931–33*—Continued

5-7-5 INORGANIC FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING

Placement of first application of fertilizer	Experiment no. 7 planted Sept. 10, 1932, Leon fine sand							Experiment no. 8 planted Sept. 12, 1932, St. John's fine sand						
	Plants per 100 feet of row			Yield per acre [14]				Plants per 100 feet of row			Yield per acre [14]			
	Sept. 15	Sept. 17	Sept. 24	First picking Oct. 23	Second picking Oct. 27	Sum first and second picking	Total	Sept. 17	Sept. 19	Sept. 26	First picking Oct. 26	Second picking Oct. 29	Sum first and second picking	Total
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No fertilizer at planting, soil disturbed under seed [15]	184	283	299	2, 769	960	3, 729	5, 614	191	291	288	3, 426	1, 342	4, 768	7, 686
No fertilizer at planting, soil undisturbed under seed [15]	236	307	314	3, 434	714	4, 148	6, 306	238	292	288	3, 232	1, 553	4, 785	7, 520
Average	210	295	307	3, 102	837	4, 939	5, 960	215	291	288	3, 329	1, 447	4, 776	7, 603
In 3.5-inch band on surface of ground over seed	68	203	283	2, 321	1, 253	3, 574	6, 146	49	243	280	2. 863	1, 457	4, 320	7, 508
In 1.75-inch band 1 inch under seed	161	303	313	3, 999	896	4, 895	7, 940	121	288	302	3, 351	1, 565	4, 916	8, 332
In 1.75-inch band 3 inches under seed	245	309	321	4, 177	1, 115	5, 292	7, 542	212	313	348	3, 865	1, 389	5, 254	8, 445
In 3.5-inch band 1 inch under seed	243	323	333	3, 836	1, 148	4, 984	7, 577	230	309	329	3, 821	1, 460	5, 281	8, 343
In 3.5-inch band 3 inches under seed	267	320	325	3, 826	1, 026	4, 852	7, 269	236	306	315	3, 724	1, 662	5. 386	8, 308
Mixed with soil to a depth of 3 inches under seed	263	314	329	4, 720	831	5, 551	7, 877	237	319	342	4, 041	1, 537	5, 578	8, 660
In narrow band 2 inches to each side and 1½ inches below seed	240	309	333	4, 246	1, 221	5, 467	7, 957	224	323	333	3, 807	1, 424	5, 231	8, 238
In narrow band 3 inches to each side and 1½ inches below seed	239	311	325	4, 023	1, 641	5, 664	8, 059	180	310	328	3, 457	1, 685	5, 142	8, 039
In narrow band 4 inches to each side and 1½ inches below seed	217	307	326	4, 532	981	5, 513	7, 961	189	309	315	3, 621	1, 401	5, 022	8, 207
5-7-5 (ONE-HALF N FROM ORGANIC SOURCES) FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS AS SIDE DRESSING 3 WEEKS AFTER PLANTING														
In 3.5-inch band on surface of ground over seed	108	255	272	2, 628	1, 019	3, 647	6, 149	62	227	264	2, 399	2, 208	4, 607	7, 808
In 1.75-inch band 1 inch under seed	108	297	320	3, 234	1, 150	4, 384	6, 968	217	304	310	3, 562	1, 399	4, 960	8, 306
In narrow band 2 inches to each side and 1½ inches below seed	200	303	301	3, 389	826	4, 215	6, 653	248	297	314	3, 798	1, 598	5, 396	8, 472

10-14-10 FERTILIZER, 350 POUNDS PER ACRE AT PLANTING, 350 POUNDS AS SIDE DRESSING 3 WEEKS AFTER PLANTING

In 3.5-inch band on surface of ground over seed	52	146	162	1, 413	864	2, 277	4, 512	27	168	216	2, 103	1, 641	3, 744	7, 024
In 1.75-inch band 1 inch under seed	162	292	307	3, 304	920	4, 224	6, 412	160	294	300	3, 743	1, 390	5, 133	8, 574
In 3.5-inch band 1 inch under seed	255	306	319	3, 532	744	4, 276	6, 240	233	307	320	3, 744	1, 248	4, 992	8, 533
Mixed with soil to a depth of 3 inches under seed	255	305	316	4, 037	606	4, 643	6, 497	238	311	326	3, 750	1, 615	5, 365	8, 578
In narrow band 2 inches to each side and 1½ inches below seed	234	313	320	3, 666	1, 014	4, 680	6, 298	239	303	330	3, 586	1, 838	5, 324	8, 369

[14] 4 pickings 3 to 4 days apart.

[15] Fertilizer applied as side dressings, 700 pounds per acre 1 and 3 weeks after planting, in furrows 2½ inches deep, 4 inches to one side of row.

TABLE 5.—*Plants above ground per 100 feet of row and yield of green beans per acre for various placements of fertilizer at Winter Garden, Fla., 1931–33*—Continued

5-7-5-INORGANIC FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING

Placement of first application of fertilizer	Experiment no. 9 planted Sept. 21, 1933, Leon fine sand							Experiment no. 10 planted Sept. 20, 1933, St. John's fine sand						
	Plants per 100 feet of row			Yield per acre [16]				Plants per 100 feet of row			Yield per acre [16]			
	Sept. 26	Sept. 28	Oct. 5	First picking Nov. 6	Second picking Nov. 10	Sum first and second pickings	Total	Sept. 25	Sept. 27	Oct. 4	First picking Nov. 6	Second picking Nov. 13	Sum first and second pickings	Total
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
No fertilizer at planting, soil disturbed under seed [17]	205	290	289	4, 609	653	5, 262	7, 250	202	271	266	4, 820	2, 010	6, 830	8, 337
No fertilizer at planting, soil undisturbed under seed [17]	182	298	306	4, 332	585	4, 917	7, 356	200	278	290	5, 841	2, 143	7, 984	9, 855
Average	194	294	298	4, 471	619	5, 090	7, 303	201	275	278	5, 331	2, 076	7, 407	9, 096
In 3.5-inch band on surface of ground over seed	143	232	250	3, 392	690	4, 082	6, 212	148	198	200	5, 040	2, 357	7, 397	9, 568
In 1.75-inch band 1 inch under seed	79	180	256	3, 010	820	3, 830	6, 552	38	163	230	3, 776	2, 052	5, 828	9, 505
In 1.75-inch band 3 inches under seed	246	304	312	4, 568	590	5, 158	7, 698	183	259	267	5, 162	2, 008	7, 170	9, 873
In 3.5-inch band 1 inch under seed	72	214	301	3, 022	819	3, 841	6, 769	19	131	222	2, 783	2, 646	5, 429	9, 124
In 3.5-inch band 3 inches under seed	256	301	305	4, 482	721	5, 203	7, 849	183	242	249	5, 005	2, 596	7, 601	10, 251
In narrow band 2 inches to one side and 1½ inches below seed	197	307	320	4, 858	712	5, 570	7, 578	189	265	276	5, 944	1, 766	7, 710	9, 633
In narrow band 4 inches to one side and 1½ inches below seed	167	309	330	4, 562	573	5, 135	7, 476	184	272	382	5, 785	1, 917	7, 702	9, 265
In narrow band 2 inches to each side and 1½ inches below seed	208	305	328	4, 935	714	5, 649	7, 893	210	279	297	5, 817	2, 333	8, 150	10, 167
In narrow band 3 inches to each side and 1½ inches below seed	179	313	337	4, 803	871	5, 674	7, 802	183	279	296	5, 783	1, 954	7, 737	9, 834
In narrow band 4 inches to each side and 1½ inches below seed	167	304	312	4, 707	613	5, 320	7, 525	150	272	280	5, 597	1, 947	7, 544	9, 731

5-7-5 (ONE-HALF N FROM ORGANIC SOURCES) FERTILIZER, 700 POUNDS PER ACRE AT PLANTING, 700 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING														
In 3.5-inch band on surface of ground over seed	159	242	256	4,064	530	4,594	6,616	200	237	235	5,223	1,464	6,687	8,686
In 1.75-inch band 1 inch under seed	75	223	286	3,357	871	4,228	7,137	122	229	253	4,530	2,128	6,658	9,418
In narrow band 2 inches to each side and 1½ inches below seed	209	289	309	4,573	526	5,099	7,107	239	291	289	5,839	1,782	7,621	9,801
10-14-10 FERTILIZER, 350 POUNDS PER ACRE AT PLANTING, 350 POUNDS SIDE DRESSING 3 WEEKS AFTER PLANTING														
In 3.5-inch band on surface of ground over seed	146	236	247	3,575	441	4,016	5,853	182	216	213	5,149	1,910	7,059	8,819
In 1.75-inch band 1 inch under seed	128	228	272	3,240	570	3,810	6,336	95	192	242	4,774	2,115	6,889	9,690
In 1.75-inch band 3 inches under seed	254	302	317	4,813	683	5,496	7,586	221	274	266	5,504	1,827	7,331	9,522
In 3.5-inch band 1 inch under seed	127	229	266	2,817	676	3,493	5,951	80	189	227	4,304	2,391	6,695	9,984
In 3.5-inch band 3 inches under seed	250	296	306	4,730	589	5,319	7,602	193	252	262	5,713	2,152	7,865	10,497
In narrow band 2 inches to one side and 1½ inches below seed	192	301	314	3,923	580	4,503	6,316	193	247	255	6,044	2,054	8,098	10,032
In narrow band 2 inches to each side and 1½ inches below seed	196	283	297	4,116	807	4,923	6,797	193	241	247	5,891	1,938	7,829	9,897
In narrow band 3 inches to each side and 1½ inches below seed	214	303	319	4,550	598	5,148	7,130	201	254	271	5,885	2,285	8,170	9,892
In narrow band 4 inches to each side and 1½ inches below seed	204	301	314	4,338	735	5,073	7,076	201	261	279	5,685	1,821	7,506	9,627

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[16] 4 pickings 3 to 5 days apart.

[17] Fertilizer applied as side dressings of 700 pounds per acre 1 and 3 weeks after planting, in furrows 2½ inches deep and 4 inches to one side of plants.

The two plots to which no fertilizer was applied at time of planting received the initial application at the time of or soon after the second stand count. The initial fertilizer application was made in a furrow 2.5 inches deep about 4 inches to one side of the row and it is not likely that the stand of plants at the final count, which followed in a few days, was affected by this fertilizer. The first and last stand counts shown in the tables are considered a true indication of the germination of the seed under the existing unfertilized soil conditions. Where no fertilizer was applied at time of planting, fewer plants in most cases had appeared at both the first and last counts than where fertilizer was placed in the most advantageous positions. Evidently a number of weak plants were unable to come up without the added strength provided by the fertilizer.

For the purpose of making direct comparisons of the plots unfertilized at planting with those fertilized in the early germination period, the seed for one of the unfertilized plots were deposited in disturbed soil and for the other in undisturbed soil. These seedbed conditions correspond to those of placements under the seed and of placements at the sides or above the seed, respectively. A larger number of plants came up when the seed were planted in undisturbed soil as compared to disturbed soil, the average number per 100 feet for all experiments being 300 and 285, respectively. The largest average number of plants was also found on the undisturbed soil at the first count, but exceptions are noted under the dry conditions of 1931 and 1932. When the topsoil was unusually dry and the seedbed was not disturbed, the seed were deposited in comparatively dry soil; but when the seedbed was disturbed moist soil from below was brought into contact with the seed, in which case germination was hastened. The results show that under average conditions most rapid germination and best stand of plants are obtained when the seed are planted in firm soils where capillarity is not broken.

SINGLE-STRENGTH FERTILIZER

Fertilizers 5–7–5 placed on the surface of the ground above the seed retarded germination and usually reduced the final stand of plants compared to the unfertilized checks. The influence of the surface placement on stand was dependent to a considerable extent on weather conditions between the time of planting and the emergence of the plants above ground. A moderate amount of rainfall soon after planting apparently carried the soluble fertilizer salts into the seed zone and markedly retarded germination, as indicated by the first stand counts particularly in experiments nos. 6, 7, and 8 (table 5). With little rain immediately following planting, there was less retardation of germination with the surface application especially in experiments nos. 1, 3, and 5, as shown in the table and in figure 11.

The fertilizer was placed in the furrows in contact with the seed only in the 1931 experiments, the results of which are given in table 5. Seven hundred pounds per acre of 5–7–5, or 350 pounds per acre of 10–14–10 fertilizer, in contact with the seed completely inhibited germination. The condition of the seed at the end of a 7-day period is shown in figure 12. At the end of 1 week these plots were replanted in order to prevent any advantage to adjacent rows later resulting from lack of plant competition. While a limited number of plants might have emerged after the first week, the inhibition of germination for 1 week was considered sufficient grounds for discontinuing the contact treatment.

In most of the experiments fertilizer placed in a band 1.75 or 3.5 inches wide, 1 inch under the seed, retarded germination of the seed and plant growth and reduced the final stands of plants. The early effects of this placement are shown in figures 11, *c*, and 13, *c*. Comparatively few plants had appeared above ground at the first count.

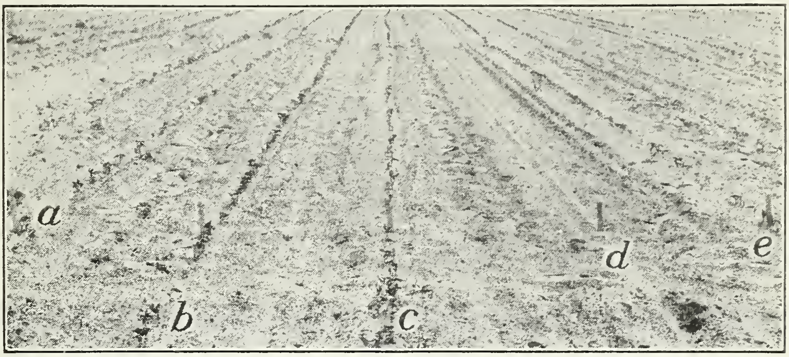

FIGURE 11.—Effect of different placements of 700 pounds per acre of 5-7-5 fertilizer on beans on Leon fine sand: *a*, Fertilizer mixed with soil below seed; *b*, applied 3 inches below seed in band 1.75 inches wide; *c*, applied 1 inch under seed in band 1.75 inches wide; *d*, in contact with seed; *e*, on surface of soil above seed.

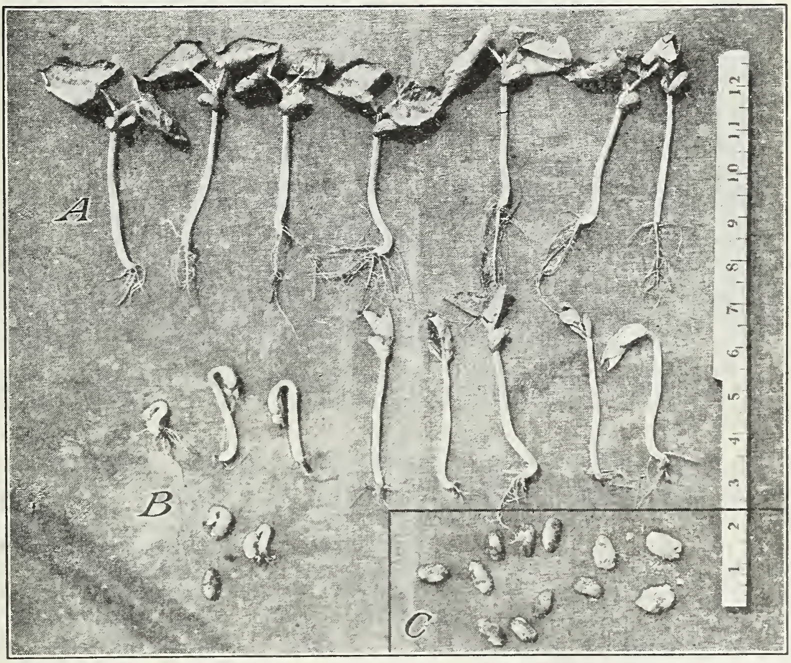

FIGURE 12.—Bean seed and bean seedlings dug from plots in fertilizer-placement experiments 7 day after planting on Leon fine sand with 700 pounds per acre of 5-7-5: *A*, Fertilizer in band 2 inches to each side of and 1.5 inches below level of seed; *B*, fertilizer placed 1 inch under the seed in 1.75-inch band; *C*, fertilizer in contact with the seed.

Under favorable moisture conditions such as those of experiments nos. 1, 6, 7, and 8, germination was not materially delayed. Germination was delayed and final stands reduced unless frequent rains occurred after planting even though the soil moisture at time of planting was relatively high. Placements in 3.5-inch bands, 1 inch under the seed, generally had about the same effect on germination as in 1.75-inch bands; however, the 3.5-inch band was superior in about half of the comparisons, and the average number of plants coming up in all experiments was somewhat higher for the 3.5-inch band than for the 1.75-inch band. The average results for the placements in the 1932 and 1933 experiments are shown in table 6.

Fertilizers placed 3 inches under the seed in bands 1.75 or 3.5 inches wide, as shown in figures 11, *b* and 13, *d*, did not retard seed germination or result in poor stands. The number of plants above ground at both the first and last counts were higher in most cases than those of the unfertilized rows. In experiment no. 5 (table 5) no appreciable rain fell for 10 days after planting and germination was delayed by fertilizer in this placement, but the final stands were nearly as good as those of the rows to which no fertilizer was applied. The wider band does not appear to be advantageous with respect to either earliness of germination or final stand of plants when the fertilizer is placed 3 inches under the seed, and this depth was much superior to 1 inch under the seed.

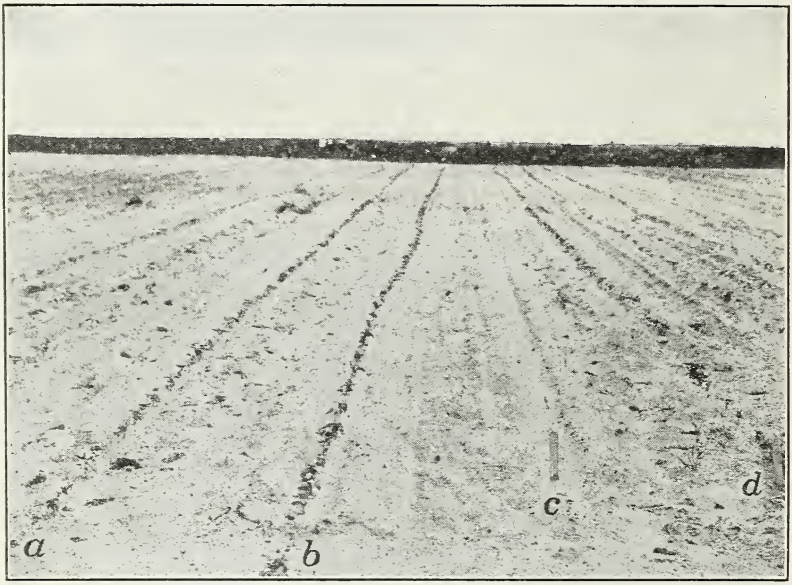

FIGURE 13.—Effect of 700 pounds per acre of 5–7–5 fertilizer applied at planting on stand of beans on Leon fine sand: *a*, Fertilizer applied 4 inches to each side and 1.5 inches below level of seed; *b*, 2 inches to each side and 1.5 inches below level of seed; *c*, 1 inch under seed in 3.5-inch band; *d*, 3 inches under seed in 3.5-inch band.

Fertilizer was placed in a 1.75-inch band 2 inches under the seed only in experiment no. 6. The moisture conditions in this experiment were favorable for germination and placements under the seed did not affect germination to any extent.

Table 6.—*Average of first and final stand counts in plants per 100 feet of row for various placements at time of planting of different fertilizers applied in equivalent amounts per acre near Winter Garden, Fla.*

[Averages for experiments nos. 5 to 10 inclusive, 1932–33]

Placement of initial application of fertilizer	Plants per 100 feet of row					
	5–7–5 inorganic fertilizer 700 pounds per acre[1]		5–7–5 fertilizer (one-half N. from organic sources) 700 pounds per acre[1]		10–14–10 fertilizer 350 pounds per acre[1]	
	First count	Final count	First count	Final count	First count	Final count
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Check, no fertilizer at planting, soil disturbed under seed[2]	211	294				
Check, no fertilizer at planting, soil undisturbed under seed[2]	217	310				
Average	214	302				
3.5-inch band on surface of ground over seed	100	259	131	265	106	227
1.75-inch band 1 inch under seed	104	259	108	287	101	261
1.75-inch band 3 inches under seed	204	310				
3.5-inch band 1 inch under seed	141	295			150	290
3.5-inch band, 3 inches under seed	238	305				
Narrow band 2 inches to each side 1.5 inches below level of seed	236	326	233	309	222	307
Narrow band 3 inches to each side 1.5 inches below level of seed	217	327				
Narrow band 4 inches to each side 1.5 inches below level of seed	201	317				

[1] Fertilizer in an amount equal to the initial application was side dressed in all tests 3 weeks after planting.

[2] Test served as a check on germination, initial application of 5–7–5 all-mineral fertilizer at the rate of 700 pounds per acre was side dressed 1 week after planting.

In one treatment the fertilizer was mixed with the soil under the seed, which was first deposited in a 3.5-inch band 3 inches below the level at which the seed were planted. A special mixing shovel operating at a depth slightly below the fertilizer band mixed the fertilizer with the soil, and the seed were deposited immediately above the resulting mixture. The relative standing of this placement with respect to germination in most of the experiments is between the placements in bands 1 inch and 3 inches under the seed where the fertilizer was not mixed with the soil. Since the center of the fertilizer and soil mixture is approximately 2 inches under the seed, such a relative standing might be anticipated. The effects of this treatment on rapidity of germination and stand are illustrated in figure 11, *a*. The stand counts are shown in table 5. The test was not included in the 1933 experiments.

When the fertilizer was placed in a narrow band on one or both sides of the seed, a larger number of plants at the final count was obtained than from other placements. In the main series of treatments the fertilizer was placed 1.5 inches below the level of the seed in bands 2 and 4 inches to each side of the seed. Other depths and distances from the seed row were employed in some experiments. In general, the rapidity of germination when fertilizer was placed to the side of the seed, as indicated by the first stand count, was equal to that of the unfertilized rows. Early developments of the crop for the side placement of fertilizer are illustrated in figures 12, *A* and 13, *a* and *b*. The number of plants at the final count approximately 2 weeks after planting was greater than with the other treatments, including the plants unfertilized at time of planting.

Considering the placements 2 and 4 inches to each side of the seed row, the number of plants at both the first and last counts was less for the 4-inch distance in most instances. Apparently the fertilizer was too far from the seed to be of any early benefit. Experiments (*10*) with cotton under similar soil conditions have shown that some of the soluble salts enter the seed zone during the germination period when the fertilizer is placed in a band 1.5 inches to each side of the row, but do not reach the seed zone during this period when placed 3.5 inches from the row. In opening furrows to place the fertilizer closer than 1.5 to 2 inches from the row, the intervening block of soil is reduced to such width that the soil immediately under the seed either may be disturbed or readily dries under unfavorable weather conditions to such an extent that germination is affected.

In experiments nos. 5 to 10, inclusive, fertilizer was applied in a band 3 inches to each side of the row and 1.5 inches below the seed level. Although the records on germination compare favorably with those of the 2-inch distance to each side of the row, they might be considered slightly inferior.

Fertilizer was applied in bands 2 inches to each side of the seed row and 0.5 inches and 2.5 inches below the seed level only in experiment no. 6. The prevailing conditions were favorable for seed germination and the stands of plants compared favorably with those for placements 1.5 inches below the level of the seed. The results are given in table 5.

In experiments nos. 9 and 10 (table 5) the fertilizer was placed in a band at only one side of the row at distances of 2 and 4 inches from the seed. The number of plants appearing above ground at the first and last counts for placements 2 inches to one side did not differ widely from placements to both sides of the seed, but when the fertilizer was 4 inches from the seed there appears to be some slight benefit by placing the fertilizer to only one side of the seed.

Three methods of fertilizer application resembling local practices were included in experiment no. 6 (table 5). The fertilizer was applied on the surface of the ground in a band 6 inches wide. In one procedure a shovel 4 inches wide operated at a depth of 1.5 inches threw the fertilizer to each side of the resulting furrow in which the seed shoe traveled. The fertilizer mixed with the soil was finally placed to the sides and above the seed. In a second procedure, a 5-tooth scratcher operating at a depth of 0.75 inch mixed the fertilizer with the surface soil in a strip approximately 6 inches wide. The planter shoe traveled in the center of the band, depositing the seed 0.5 inch below the soil-fertilizer mixture, and in covering the seed part of the fertilizer was carried with the soil into the furrow over the seed, the main portion remaining in the surface soil at each side of the seed row. In a third procedure, soil was thrown over the fertilizer band by means of disks and the bed was lowered to a height of 2 inches above the fertilizer by means of lateral scrapers on the seed shoe. The seed was planted 1.5 inches deep. The resulting fertilizer placement was a 6-inch band 0.5 inch under the seed in a slightly raised seed bed.

The conditions for experiment no. 6 were highly favorable for germination and the three local fertilizer-application methods did not give results differing materially from those of the other treatments.

In fact, all fertilizer placements in this experiment gave both rapid germination and a good final stand of plants, with the exception of the surface placement which was somewhat inferior.

INORGANIC VERSUS ORGANIC NITROGEN FERTILIZER

In experiments 5 to 10, inclusive, fertilizers containing nitrogen entirely from inorganic sources were used in the main series of placements, and in three placements the results are compared with similar placements of a fertilizer containing 50 percent of inorganic nitrogen and 50 percent of organic nitrogen.

The relative standing of the various placements with regard to germination is, in general, the same for the two lots of 5–7–5 fertilizer. In addition to the results of individual experiments presented in table 5, general averages of comparable tests are given in tables 6 and 7. When the two fertilizers were placed in a band at each side of the seed row, the number of plants did not differ widely at either the first or the final count.

Table 7.—*Comparative average stands, plants per 100 feet, and yields of green beans per acre, for three placements of 5–7–5 inorganic, 5–7–5 (one-half N organic), and 10–14–10 fertilizer at Winter Garden, Fla., 1931–33*

Placement of first application of fertilizer	Type and rate of application of fertilizer per acre	Average stand of plants per 100-foot row				Average first picking and total yield			
		1932–33		1931–33		1932–33		1931–33	
		First count	Final count	First count	Final count	First picking	Total	First picking	Total
		No.	*No.*	*No.*	*No.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
In 3.5-inch band on surface of ground over seed.	5–7–5 all-mineral, 700 pounds at planting, 700 pounds side dressing.	100	259	------	------	2,765	6,436	------	------
	5–7–5 (one-half N organic), 700 pounds at planting, 700 pounds side dressing.	131	265	130	268	2,953	6,422	2,715	6,305
	10–14–10 all-mineral, 350 pounds at planting, 350 pounds side dressing.	106	227	94	246	2,479	5,767	2,351	5,900
In 1.75-inch band 1 inch under seed.	5–7–5 all-mineral, 700 pounds at planting, 700 pounds side dressing.	104	259	------	------	2,740	6,831	------	------
	5–7–5 (one-half N organic), 700 pounds at planting, 700 pounds side dressing.	108	287	76	250	2,972	7,049	2,482	6,503
	10–14–10 all-mineral, 350 pounds at planting, 350 pounds side dressing.	101	261	70	222	2,906	6,534	2,348	5,996
In narrow bands 2 inches to each side, 1½ inches below seed.	5–7–5 all-mineral, 700 pounds at planting, 700 pounds side dressing.	236	326	------	------	3,973	7,538	------	------
	5–7–5 (one-half N organic), 700 pounds at planting, 700 pounds side dressing.	233	309	227	302	3,739	7,102	3,506	6,958
	10–14–10 all-mineral, 350 pounds at planting, 350 pounds side dressing.	222	307	214	301	3,666	7,053	3,427	7,079

The two 5–7–5 fertilizers generally gave somewhat similar germination results, when placed either on the surface of the ground or in a band 1 inch under the seed. The minor differences are in favor of the fertilizer containing one-half organic nitrogen. In both of these placements the fertilizers delayed germination and reduced the final stands of plants.

DOUBLE-STRENGTH FERTILIZER

A 10–14–10 fertilizer, containing twice the quantity of plant food constituents as the 5–7–5 mixture, was applied in all experiments in a limited number of placements. The results of individual tests are presented in table 5 and comparable averages are shown in tables 6 and 7. The relative standing of the different placements with regard to the numbers of plants at the first and final counts is similar to that of the same placements of the single-strength fertilizer. Application of the fertilizer in contact with the seed inhibited germination for 1 week, at which time the plats were replanted to avoid any advantage to adjacent rows.

It is of interest to note in experiments nos. 3, 4, 6, 7, and 8, where rains immediately followed planting as shown in table 3, that placement of the fertilizer on the ground surface delayed germination, as indicated by the relatively small number of plants at the first count. Retardation of germination and seedling growth is illustrated in figure 14. On the other hand, in experiments nos. 1, 2, 5, 9, and 10 where rains did not fall immediately after planting, little delay of germination was observed. The effects of the surface placement seem dependent to a considerable extent on the amount and distribution of rainfall following planting. Evidently the soluble salts are readily carried down into the seed zone with the moisture of a comparatively light rain. A reduction in the number of plants appearing above ground resulted from the surface placement as compared to the plots unfertilized at time of planting.

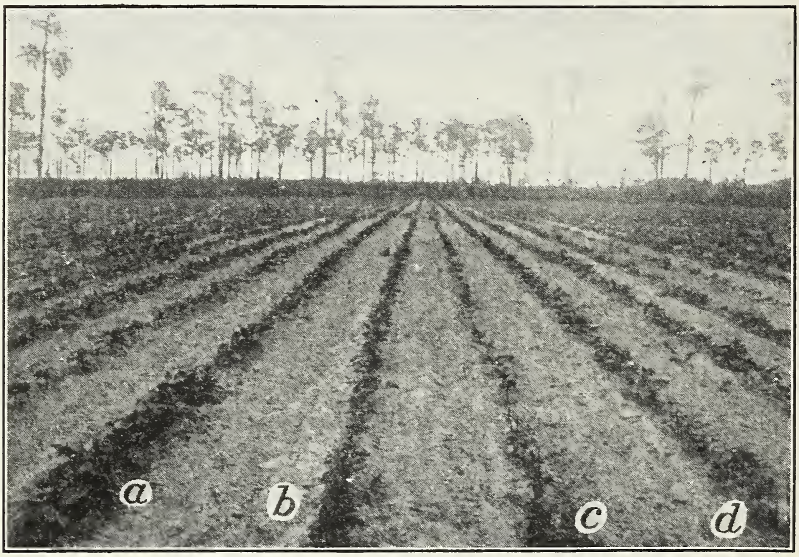

FIGURE 14.—Snap beans planted September 10 on Leon fine sand, photographed September 25, 1932, at Winter Garden, Fla.: *a*, 5–7–5 all-mineral fertilizer at 700 pounds per acre mixed with the soil under the seed to a depth of 3 inches; *b*, no fertilizer at planting; *c*, 10–14–10 fertilizer at 350 pounds per acre placed on the surface of the ground above the seed; *d*, 10–14–10 fertilizer at 350 pounds per acre placed in a band 1.75 inches wide 1 inch under the seed.

The effects of the double-strength fertilizer on germination when applied in a band 1 inch under the seed, with the rainfall conditions just described, were in general opposite to those of the surface placement. Since the movement of the soluble salts with the soil moisture was in the opposite direction with respect to the seed, the results are in accord with theoretical considerations. The variation in stand with weather conditions was not so great as in the case of the surface placement, presumably because in the case of the light rain either no moisture reached the zone of the fertilizer or the amount of moisture reaching that zone was insufficient to cause an appreciable downward movement of the soluble salts. Fertilizer placed 1 inch under the seed either in a 1.75-inch or a 3.5-inch band (fig. 15, *b*) materially reduced the number of plants that came up.

Mixing of the fertilizer under the seed to a depth of 3 inches gave a material reduction in the number of plants under the less favorable weather conditions of experiments nos. 2, 3, 4, and 5. Under the more favorable weather conditions of experiments nos. 6, 7, and 8 germination was equal to that of the unfertilized plots. The test was not included in experiments nos. 1, 9, and 10 because the crop residue previously plowed under did not permit satisfactory mixing of the fertilizer with the soil.

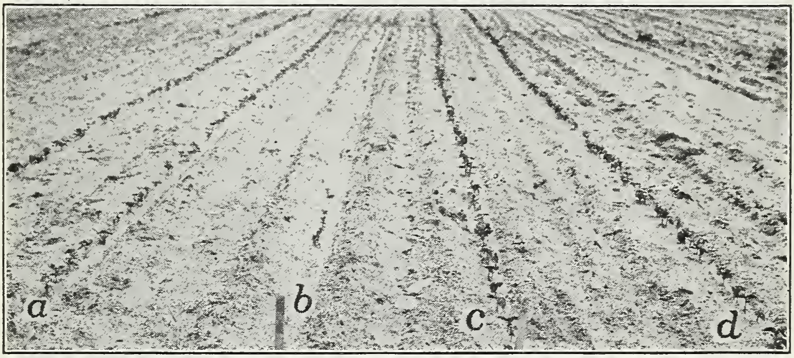

FIGURE 15.—Effect of 350 pounds of 10–14–10 fertilizer on germination of beans on Leon fine sand: *a*, No fertilizer; *b*, fertilizer applied 1 inch below seed in 3.5-inch band; *c*, 2 inches to each side of and 1.5 inches below level of seed; *d*, 3 inches to each side of and 1.5 inches below level of seed.

Placement of the fertilizer in a narrow band 2 inches to each side of the seed row and 1.5 inches below the seed level resulted in a larger number of plants at both first and final counts in almost all of the experiments than other placements of the 10–14–10 fertilizer. Somewhat similar stands of plants were obtained for the side placement of the double and single-strength fertilizers.

Application of the fertilizer in bands 3 inches to each side of the seed row and 1.5 inches below the seed level, in experiments nos. 1, 9, and 10, gave germination results somewhat similar to placements 2 inches to the sides of the seed row (fig. 15, *c*, *d*). Placements 3 inches to the side of the seed were possibly better under the dry conditions of experiments 9 and 10. Fertilizer placed at a distance of 4 inches to each side of the seed in experiments 9 and 10 gave results almost identical with placements 3 inches to the side.

The application of fertilizer in bands 1.75 and 3.5 inches wide, 3 inches under the seed in experiments 9 and 10, resulted in numbers of plants at the first and final counts equal to those of side placements and considerably greater than those of placements 1 inch under the seed. Placements 3 inches under the seed, in narrow or wide bands, gave somewhat similar results.

In experiment no. 6 the 10–14–10 fertilizer applied in accordance with two local practices gave results somewhat similar to those from placements below the seed, under the prevailing favorable conditions. Application of fertilizer on the surface of the ground and covering with 2 inches of soil, which results in a slightly raised seedbed, delayed germination. Such deterrent effects under average conditions might be anticipated since the fertilizer is located 0.5 inch under the seed and the raised loose seedbed permits relatively rapid drying of the surface soil.

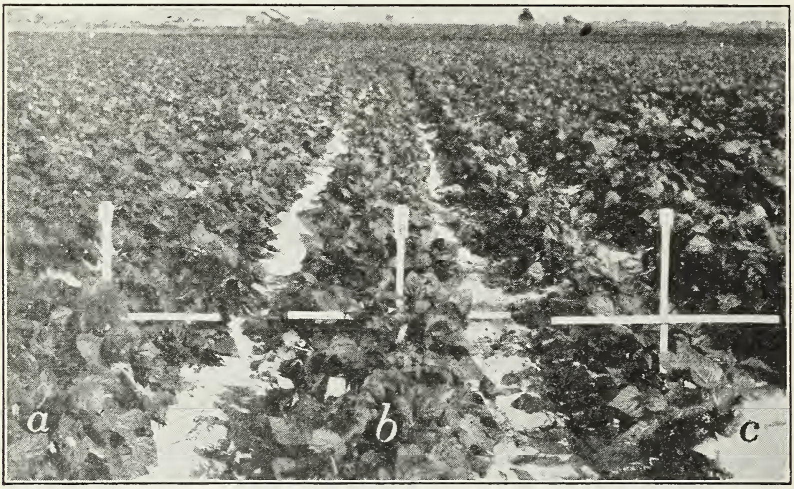

Figure 16.—Effect of different placements of 5-7-5 fertilizer on growth of beans on Leon fine sand, 700 pounds per acre of fertilizer applied at planting on a level 1.5 inches below the seed: *a*, 2 inches to each side; *b*, 4 inches to each side and 700 pounds as side dressing 21 days later; *c*, no fertilizer applied at planting, 700 pounds per acre applied as a side dressing 7 days after planting and 700 pounds 21 days after planting.

EFFECT OF FERTILIZER PLACEMENT ON PLANT GROWTH

Differences in plant growth for the various placements of the fertilizer resulted largely from the adverse effects during the germination period. Delay of germination and injury to the young seedlings were reflected in the later development of the crop. Differences in plant growth for various placements of the fertilizer are shown in figures 16 and 17. In general, most rapid growth of plants occurred where the fertilizer was applied in a band at either one or both sides of the row, in a band 3 inches under the seed, mixed with the soil under the seed, and as applied in the three representative local practices previously described on page 4. The plants to which fertilizer was not applied until approximately 1 week after planting, were of a lighter green color as compared to those on plots fertilized at time of planting. The lighter color was distinguishable throughout the season in some cases.

There was evidence of injury to the plants where the fertilizer was placed in a band 1 inch under the seed and on the surface of the ground. The shedding of leaves which had turned brown was particularly noticeable during the dry seasons. Where fertilizers were placed near the seed, plant injury appeared to be most severe with the double-strength fertilizer and least noticeable with the single-strength fertilizer having one-half its nitrogen from organic sources. Fertilizer placed on the surface of the ground over the seed caused injury to the plants and reduced the stand, especially with the double-strength fertilizer. Uusually, however, the injury was confined to the shedding of the first leaves and the plant continued to live and develop new foliage.

EFFECT OF FERTILIZER PLACEMENT ON YIELD OF BEANS

In discussing yields of snap beans it is recognized that earliness of maturity is an important factor that must be considered in conjunction with total yield. The yield at the first picking in these experiments may be considered an indication of the earliness of maturity. The highest quality beans usually are harvested at the first picking, and it is therefore advantageous to obtain a high yield at the early picking, because of the greater profit which results. Another point of advantage is that the danger of damage from frost in the Winter Garden district is lessened to some extent by early maturity of beans. Particular attention, then, should be given to the harvest at first picking as well as to the total yield. Different amounts of snap beans harvested at the first picking for various placements of the fertilizer are shown in figures 18 and 19.

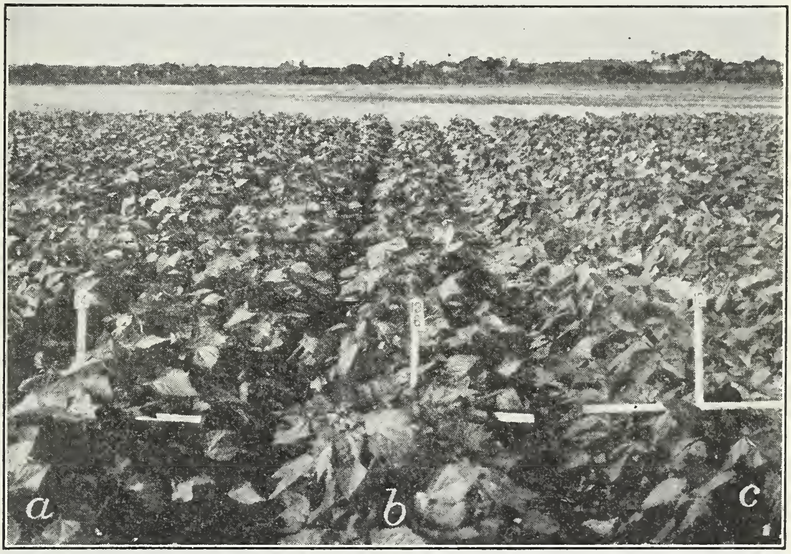

FIGURE 17.—Growth of beans on Leon fine sand from 10–14–10 fertilizer applied 350 pounds per acre at planting and 350 pounds 2 weeks later: *a*, Fertilizer applied 2 inches to each side of and 1.5 inches below level of seed; *b*, mixed with soil under seed to a depth of 3 inches; *c*, 1 inch below seed in 1.75-inch band.

The yield of beans at first and second pickings and the total yields are given in table 5. The yields at first picking and total yields for the main series of placements of the 5–7–5 fertilizer are shown in table 8 for convenience in making comparisons. The relative standing of the various fertilizer placements with respect to yields is generally similar to that for germination or number of plants coming up. Any significant reduction in the number of plants coming up was reflected in the total yield and the yield at first picking.

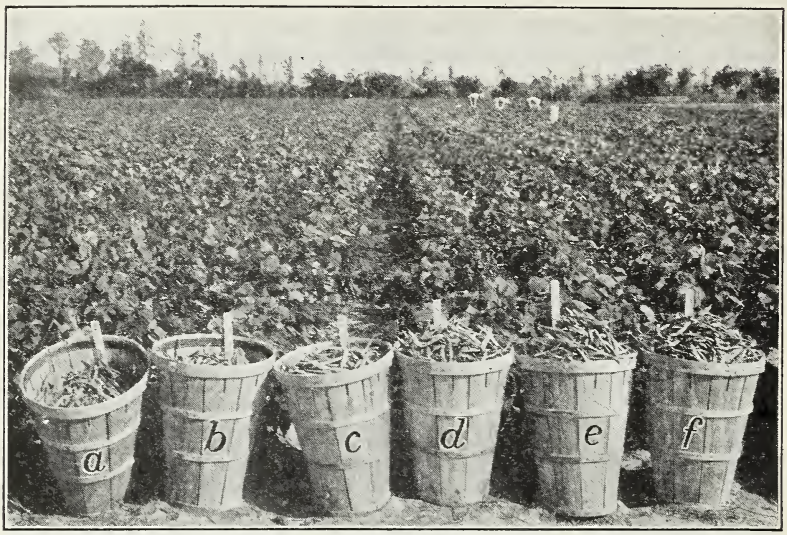

FIGURE 18.—Yield of beans at first picking from 100-foot rows, when 700 pounds per acre of 5–7–5 fertilizer was applied at planting and 700 pounds 2 weeks later: *a*, Fertilizer applied 1 inch under seed in bands 3.5 inches wide; *b*, on surface of ground above seed; *c*, 3 inches under seed in band 3.5 inches wide; *d*, no fertilizer at planting, side dressed 7 days later; *e*, 2 inches to one side of seed and 1.5 inches below level of seed; *f*, 2 inches to each side of seed and 1.5 inches below level of seed.

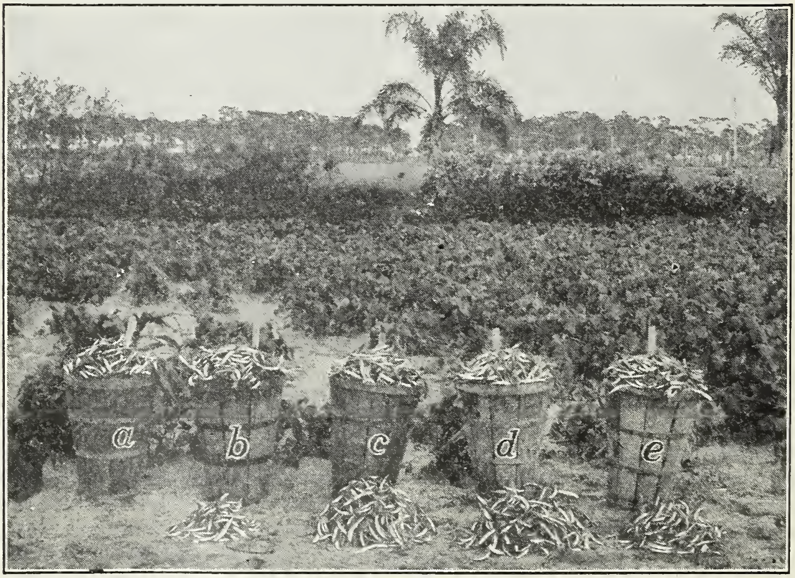

FIGURE 19.—Yield of beans at first picking from 100-foot rows, when 700 pounds per acre of 5–7–5 fertilizer was applied at planting and 700 pounds 2 weeks later: *a*, Fertilizer applied on surface of ground above seed; *b*, 1 inch under the seed in band 3.5 inches wide; *c*, 4 inches to one side, 1.5 inches below level of seed; *d*, 4 inches to each side, 3 inches below level of seed; *e*, 2 inches to each side and 1.5 inches below level of seed.

TABLE 8.—*Yields of green beans per acre, for the principal placements of 5–7–5 fertilizer at Winter Garden, Fla.*

YIELD AT FIRST PICKING

Placement of initial application of fertilizer, 700 pounds per acre [1]	Placement no.[2]	Experiments nos. 1 to 4, in 1931 (fertilizer nitrogen one-half from organic sources)					Experiments nos. 5 to 8, in 1932 (all-mineral fertilizer)					Average for experiments nos. 1 to 8	Experiments nos. 9 and 10, in 1933 (all-mineral fertilizer)			Average for all experiments
		1	2	3	4	Average	5	6	7	8	Average		9	10	Average	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Soil disturbed under seed, fertilizer side-dressed [3]	1	1, 205	1, 945	3, 285	3, 802	2, 559	1, 771	1, 690	2, 769	3, 426	2, 414	2, 486	4, 609	4, 820	4, 715	2, 932
Soil undisturbed under seed, fertilizer side-dressed [3]	2	692	1, 598	2, 623	3, 997	2, 228	1, 516	1, 762	3, 434	3, 232	2, 486	2. 357	4, 332	5, 841	5. 087	2, 903
Average	------	948	771	2, 954	3, 900	2, 394	1, 644	1, 726	3, 102	3, 329	2, 450	2, 422	4, 471	5, 331	4, 901	2, 918
3.5-inch band on surface of ground over seed	3	1, 415	1, 756	2, 549	3, 709	2, 357	1, 558	1, 416	2, 321	2, 863	2, 040	2, 198	3, 392	5, 040	4, 216	2, 602
1.75-inch band 1 inch under seed	4	901	555	2, 183	3, 347	1, 747	380	1, 922	3, 999	3, 351	2, 413	2, 080	3, 010	3, 776	3, 393	2, 342
1.75-inch band 3 inches under seed	5	1, 818	2, 620	3, 364	4, 691	3, 123	2, 070	2, 736	4, 177	3, 865	3, 212	3, 167	4, 568	5, 162	4, 865	3, 507
3.5-inch band 1 inch under seed	6	132	1, 704	2, 484	2, 286	1, 651	1, 296	2, 281	3, 836	3, 821	2, 809	2, 230	3, 022	2, 783	2, 903	2, 365
3.5-inch band 3 inches under seed	7	1, 616	2, 568	3, 256	4, 366	2, 952	2, 448	2, 561	3, 826	3, 724	3, 140	3, 046	4, 482	5, 005	4, 744	3, 385
Mixed with soil under seed to depth of 3 inches	8	978	1, 195	2, 402	2, 879	1, 864	2, 103	2, 167	4, 720	4, 041	3, 258	2, 561	(4)	(4)	------	------
Narrow band 2 inches to each side 1.5 inches below the seed	9	1, 500	3, 216	3, 410	4, 502	3, 157	2. 067	2, 966	4, 246	3, 807	3, 272	3, 214	4, 935	5, 817	5, 376	3, 647
Narrow band 3 inches to each side 1.5 inches below seed	------	------	------	------	------	------	2, 172	2, 643	4, 023	3, 457	3, 074	------	4, 803	5, 783	5, 293	------
Narrow band 4 inches to each side 1.5 inches below the seed	10	1, 271	3, 269	3, 191	4, 469	3, 050	1, 981	2, 499	4, 532	3, 621	3, 158	3, 104	4, 707	5, 597	5, 152	3, 514

TOTAL YIELD

Placement of initial application of fertilizer, 700 pounds per acre [1]	Placement no.[2]	Experiments nos. 1 to 4, in 1931 (fertilizer nitrogen one-half from organic sources)					Experiments nos. 5 to 8, in 1932 (all-mineral fertilizer)					Average for experiments nos. 1 to 8	Experiments nos. 9 and 10, in 1933 (all-mineral fertilizer)			Average for all experiments
		1	2	3	4	Average	5	6	7	8	Average		9	10	Average	
Soil disturbed under seed, fertilizer side-dressed [3]	1	3, 162	5, 239	6, 730	7, 813	5, 736	2, 682	6, 163	5, 614	7, 686	5, 536	5, 636	7, 250	8, 337	7, 794	6, 068
Soil undisturbed under seed, fertilizer side-dressed [3]	2	2, 386	4, 550	6, 643	8, 098	5, 419	2, 248	6, 313	6, 306	7, 520	5, 597	5, 508	7, 356	9, 855	8, 606	6, 128
Average	------	2, 774	4, 894	6, 687	7, 955	5, 578	2, 465	6, 238	5, 960	7, 603	5, 567	5, 572	7, 303	9, 096	8, 200	6, 098
3.5-inch band on surface of ground over seed	3	3, 786	4, 926	7, 313	8, 524	6, 137	2, 703	6, 468	6, 146	7, 508	5, 706	5. 921	6, 212	9, 568	7, 890	6, 315
1.75-inch band 1 inch under seed	4	3, 933	3, 319	6, 915	8, 564	5, 683	1, 796	6, 862	7. 940	8, 332	6, 233	5, 958	6, 552	9, 505	8, 029	6, 372
1.75-inch band 3 inches under seed	5	4, 803	6, 670	7, 754	9, 535	7, 191	4, 591	7, 939	7, 542	8, 445	7, 129	7, 160	7, 698	9, 873	8, 786	7, 485
3.5-inch band 1 inch under seed	6	1, 402	5, 672	6, 945	7, 882	5, 475	3, 903	7, 034	7, 577	8, 343	6, 714	6, 094	6, 769	9, 124	7, 947	6, 465
3.5-inch band 3 inches under seed	7	4, 283	6, 613	7, 250	9, 327	6, 868	4, 002	7, 546	7, 269	8, 308	6, 781	6, 824	7, 849	10, 251	9, 050	7, 270
Mixed with soil under seed to depth of 3 inches	8	4, 047	5, 280	7, 118	8, 432	6, 219	4, 091	7, 076	7, 877	8, 660	6, 926	6, 572	(4)	(4)	------	------
Narrow band 2 inches to each side 1.5 inches below seed	9	4, 050	6, 795	7, 183	8, 931	6, 740	3, 294	7, 681	7, 957	8, 238	6, 792	6, 766	7, 893	10, 167	9, 030	7, 219
Narrow band 3 inches to each side 1.5 inches below seed	------	------	------	------	------	------	3, 342	7, 691	8, 059	8, 039	6, 783	------	7. 802	9, 834	8, 818	------
Narrow band 4 inches to each side 1.5 inches below seed	10	3, 743	7, 081	6, 497	9, 135	6, 614	2, 980	7, 144	7, 961	8, 207	6, 573	6, 593	7, 525	9, 731	8, 628	7, 000

[1] Second application, 700 pounds per acre, side-dressed in all tests 3 weeks after planting.
[2] See fig. 20.
[3] Unfertilized at planting as a check on germination of the seed, first fertilizer application approximately 1 week after planting.
[4] Test not conducted.

SINGLE-STRENGTH FERTILIZER

Considering first the 5–7–5 fertilizer, the highest total yields for the treatments included in the experiments were obtained from placements of 1.75-inch and 3.5-inch bands 3 inches under the seed and of a narrow band either 2 or 4 inches to each side of the seed row. Since the relative standing of these four placements varied somewhat in the various experiments, the comparatively small differences in total yield are not considered highly significant except possibly in the case of the placement in bands 4 inches from the seed row which appears to be definitely inferior to the other three placements. A band 1.75 inches wide 3 inches under the seed was consistently superior to a 3.5-inch band 3 inches under the seed. A band 2 inches to each side of the row was consistently superior to a band 4 inches to each side of the row.

Placements 3 inches under the seed gave largest total yields in 1931 and 1932 in experiments nos. 1 to 8, inclusive, where rainfall was below normal. Attention is called to the fact that the fertilizer in a band 3 inches under the seed was 1.5 inches lower than that placed at the sides of the row, which may account in part for the apparent advantage of the deeper placement during a dry season. However, this is not substantiated by the result from the deep side placement used, except in experiment no. 6.

When yields at first picking are considered, the placement 2 inches to each side of the row was, on the average, superior to the band 1.75 or 3.5 inches wide 3 inches under the seed, and to the band 4 inches to each side of the row. This was especially true during the season of normal rainfall in experiments 9 and 10. The wide band appears to be inferior to the narrow band when the fertilizer is placed 3 inches under the seed.

Placements of the 5–7–5 fertilizer that resulted in low yields were initial applications 1 week after planting, placements in a 3.5-inch band on the surface of the ground, and placements 1 inch below the seed in 1.75-inch and 3.5-inch bands. The lowest average yield at first picking from these placements was obtained from the placement 1 inch under the seed in a band 1.75 inches wide, while the lowest total yield was obtained from the initial application 1 week after planting.

Fertilizer 5–7–5 mixed in the soil under the seed to a depth of 3 inches was included in experiments nos. 1 to 8, and resulted in lower total yields than placements of the fertilizer in bands 3 inches under the seed and in bands 2 inches to each side of the seed row, as shown in table 8 and figure 20. Mixing the fertilizer with the soil under the seed gave total yields that compare favorably with yields from fertilizer placed in bands 4 inches to each side of the row. Fertilizer mixed with the soil under the seed gave considerably higher yields than fertilizer applied 1 week after planting, and better than fertilizer applied on the surface above the seed or in bands 1 inch under the seed. The effect of mixing the fertilizer with the soil was variable, perhaps partly because the mixing was not uniform. The uniformity of mixing fertilizer with the soil varied somewhat under the different seedbed soil conditions.

Placements of fertilizer in 1.75-inch bands 2 inches under the seed were made in experiment no. 6, which resulted in yields between those obtained with placements 1 inch and 3 inches under the seed.

Fertilizer in narrow bands 2 inches to each side of the seed row 0.5 inch and 2.5 inches below the seed level, included in experiment no. 6, gave yields similar to placements 1.5 inches below the level of the seed. The yields for fertilizer placed in bands 3 inches to each side of the seed row, in experiments 5 to 10, inclusive, were about the same as those from fertilizers placed 2 inches to each side.

Fertilizer 5–7–5 applied in bands 2 and 4 inches to one side of the seed row, in experiments nos. 9 and 10, gave yields at the first picking not significantly different from those obtained when applied in a band at each side of the seed row. However, the total yields were higher for fertilizer applied at each side of the seed row.

The three procedures in experiment no. 6 (table 5) representing local practices, were among the most inferior treatments with respect to total yields and yields at the first picking. The low yields apparently resulted from inefficient utilization of the fertilizer rather than from any reduction in the stand of plants.

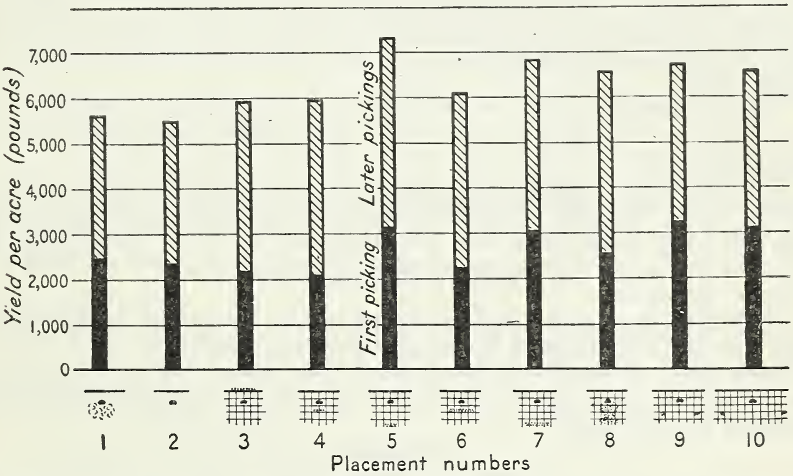

FIGURE 20.—Average yields of green beans for different placements of 5–7–5 fertilizer. Average for experiments nos. 1 to 8, (table 8). Position of fertilizer in relation to seed shown at the bottom of each bar.

INORGANIC VERSUS ORGANIC NITROGEN FERTILIZER

Fertilizer 5–7–5 containing nitrogen from inorganic sources is compared with a similar analysis containing nitrogen one-half from inorganic and one-half from organic sources. Three placements were used which are directly comparable. In addition to the yields presented for individual experiments in table 5, general averages are shown in table 7.

Fertilizers applied on the ground surface above the seed or placed 1 inch under the seed in bands 1.75 inches wide are previously shown to have given poor results, while fertilizers placed in bands 2 inches to each side of the seed row gave good results. The relative standing of the three placements is the same for the two mixtures. The side placement was decidedly superior. When the fertilizer was placed to the side of the seed, however, that containing inorganic nitrogen gave higher yields, both total and at first picking, than that containing organic nitrogen. The two mixtures gave about the same yields when the fertilizer was applied on the surface above the seed, but when applied in a band 1 inch under the seed the mixture containing one-half of the nitrogen from organic sources gave higher yields.

DOUBLE-STRENGTH FERTILIZER

Only four placements of the 10–14–10 fertilizer were carried throughout the entire study: in 3.5-inch bands on the surface of the ground above the seed; in 1.75-inch and 3.5-inch bands, 1 inch under the seed; and in narrow bands 2 inches to each side of the seed row and 1.5 inches below the level of the seed. Of these four treatments, the side placement consistently gave the highest yields particularly at the first picking. The average total yield of the side placement was 7,079 pounds per acre compared to 5,900 for the surface treatment and 5,996 and 6,270 for the 1.75- and 3.5-inch bands 1 inch under the seed, respectively. The average yield for the side placement at first picking was 3,427 pounds per acre compared to practically 2,350 for each of the other three placements.

Fertilizer was mixed with the soil under the seed in experiments nos. 2 to 8, inclusive. The average total yield for this placement was 6,377 pounds per acre as compared with 7,166 pounds for side placement and the yields at first picking were 2,386 and 3,297 pounds per acre, respectively.

The two local methods of application of the 10–14–10 fertilizer in experiment no. 6 (table 5) gave yields much lower than those of the side placement.

The 10–14–10 fertilizer was applied in a 1.75- and 3.5-inch band, 3 inches under the seed in experiments nos. 9 and 10. A higher and lower ranking of the yields in experiments nos. 9 and 10 were obtained from these placements as compared with side placements, showing no definite indication.

Placement in a band 3 inches to each side of the row in experiments nos. 1, 9, and 10 compared favorably with placement in bands 2 inches to each side. A band 4 inches to each side of the row in experiment no. 9 was superior and in experiment no. 10 was inferior to a band 2 inches to each side.

SUMMARY

Ten fertilizer-placement experiments with snap beans were conducted on Leon fine sand and St. John's fine sand near Winter Garden, Fla., in 1931, 1932, and 1933. Three fertilizers were used in the placement experiments; two contained 5 percent of ammonia, 7 percent of phosphoric acid, and 5 percent of potash, and one contained twice the amount of these fertilizer constituents. One of the 5–7–5 fertilizers contained only inorganic nitrogen and the other contained nitrogen one-half from inorganic and one-half from organic sources.

Fertilizers placed in 3.5-inch bands on the surface of the ground over the seed, mixed with the soil under the seed, or placed in bands 1.75 and 3.5 inches wide 1 inch under the seed materially delayed germination and reduced the final stand of plants under normal rainfall conditions. Fertilizers placed on the surface of the soil injured the young seedlings as they emerged.

Fertilizer placed in bands 2 or 4 inches to one or both sides of the seed row 1.5 inches below the level of the seed, and in 1.75-inch or 3.5-inch bands 3 inches under the seed, stimulated germination and plant growth sufficiently to give a final stand of plants superior to and larger than those of plants unfertilized at time of planting.

Effective rainfall immediately following planting reduced adverse effects on germination of placements under the seed, but intensified injurious effects of the placement over the seed. Lack of rainfall during the germination period intensified the adverse effects of placements under the seed. Material delay of germination and injury to stand was reflected in plant growth and yield.

Earliest germination, best stands, and most rapid growth of plants, and earliest maturity, and highest yields of green beans both at the first picking and total, were obtained with fertilizer placements in a band 3 inches under the seed, and in a narrow band 2 inches to each side of the seed row 1.5 inches below the level of the seed. The yields at first picking were slightly higher and the total yields slightly lower for the side placement.

Lower efficiency of the fertilizer as indicated by yields resulted from the placements 4 inches to the sides of the seed row, mixed in the surface soil of the seed row, and application 1 week after planting.

The three fertilizers used, in general, gave about the same relative result from various comparable placements. The 10–14–10 fertilizer and the 5–7–5 fertilizer that contained nitrogen equally from inorganic and organic sources were slightly inferior to fertilizer 5–7–5 containing only inorganic nitrogen, when placed in the most favorable positions with respect to the seed.

In obtaining the two most advantageous placements, namely, 3 inches under the seed, and 2 inches to each side of the seed row, the latter was found the more practical with respect to machine operating difficulties resulting from draft and from vegetation previously plowed under.

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